

resource recovery  
subject of seminar

House kills proposal  
to increase federal tax  
on gasoline 23 cents

Energy programs of Ford, Congress compared

Control oil prices—slowly

High risk during commercial shipment

How modern science prevents nuclear theft

Ar Plant  
ng Halt  
uested

Gasoline prices  
and common sense

Who owns that Arab oil?

Personal System Within Morgantown

y of 20,000 Builds Rapid Transit

Strip mine bill revival effort set

Peru-U.S. flights snarled by political feuding

Europe's Nuclear Program  
Too Little, Too Late

SAVE  
ELECTRICITY THIS WINTER!

Energy Saving  
Is Agency Aim

Energy Costs  
Top Expense  
In Business

Solar Energy Unit Said  
In Good Working Order

make shale oil worth effort

Gasoline prices  
and common sense

Who owns that Arab oil?

Personal System Within Morgantown

y of 20,000 Builds Rapid Transit

Strip mine bill revival effort set

Peru-U.S. flights snarled by political feuding

Europe's Nuclear Program  
Too Little, Too Late

SAVE  
ELECTRICITY THIS WINTER!

Energy Saving  
Is Agency Aim

Energy Costs  
Top Expense  
In Business

Solar Energy Unit Said  
In Good Working Order

make shale oil worth effort

# ECASTAR

ENERGY CONSERVATION: AN ASSESSMENT OF SYSTEMS, TECHNOLOGIES AND REQUIREMENTS

Energy Costs  
Top Expense  
In Business

Solar Energy Unit Said  
In Good Working Order

make shale oil worth effort

Gasoline prices  
and common sense

Who owns that Arab oil?

Personal System Within Morgantown

y of 20,000 Builds Rapid Transit

Strip mine bill revival effort set

Peru-U.S. flights snarled by political feuding

Europe's Nuclear Program  
Too Little, Too Late

SAVE  
ELECTRICITY THIS WINTER!

Energy Saving  
Is Agency Aim

Energy Costs  
Top Expense  
In Business

Solar Energy Unit Said  
In Good Working Order

make shale oil worth effort

Gasoline prices  
and common sense

Who owns that Arab oil?

Personal System Within Morgantown

y of 20,000 Builds Rapid Transit

Strip mine bill revival effort set

Peru-U.S. flights snarled by political feuding

Europe's Nuclear Program  
Too Little, Too Late

SAVE  
ELECTRICITY THIS WINTER!

Energy Saving  
Is Agency Aim

(NASA-CR-120668) ECASTAR: ENERGY CONSERVATION; AN ASSESSMENT OF SYSTEMS, TECHNOLOGIES AND REQUIREMENTS Final Report (Auburn Univ.)

CSCL 10B

G3/44

N76-21686  
THRU  
N76-21699  
Unclass  
25204

REPRODUCED BY  
NATIONAL TECHNICAL  
INFORMATION SERVICE  
U.S. DEPARTMENT OF COMMERCE  
SPRINGFIELD, VA. 22161

FINAL REPORT OF THE NASA/ASCE SYSTEMS DESIGN SUMMER FACULTY PROGRAM CONDUCTED BY THE SCHOOL OF ENGINEERING, AUBURN UNIVERSITY, AUBURN, ALABAMA, UNDER NASA GRANT NGT 01-003-044.

Focusing on Energy

Energy Costs  
Top Expense  
In Business

Solar Energy Breakthrough Sa

Offshore oil moves  
nearer to development

Environmental foes backing off

Save Energy, Money

Ford, Congress at showdown  
stage over energy policy

Asked  
Use

It is the policy of the Congress to develop on an urgent basis the technological capabilities to support the broadest range of energy policy options through conservation and use of domestic resources by socially and environmentally acceptable means.

Section 3(a)  
Federal Non-nuclear Energy Research  
and Development Act of 1974

Needless to say, this (energy conservation) is a very broad topic, and includes more than just turning off light bulbs and riding bicycles to the corner store. It also means taking a systems approach to our Nation's energy requirements. It means improving the efficiency of energy conversion, transmission, and utilization. It means implementing policies at the national and local levels that will encourage all of our citizens to conserve energy to the maximum extent feasible.

Representative Mike McCormack (D-Wash.)

... and for future generations at least we must bequeath a more rational trust and discipline ourselves to take care of our energy needs with conservation, with pollution controlled use of fossil fuels, with rapid mainstreaming of alternative forms of energy, bioconversion, solar, geothermal, and the rest.. Under stress we can do it. Under stress engineers and scientists become very, very creative . . .

Ralph Nader

A limited number of copies of this final report will be available from: ENGINEERING EXTENSION SERVICE, Auburn University, Auburn, Alabama 36830. The ECASTAR report (energy conservation) may be viewed as a companion report to MEGASTAR (energy growth). Previous summer studies by the Auburn/Marshall Summer Faculty Fellowship Systems Engineering Design Groups are listed on the inside of the back cover of this report.

## N O T I C E

THIS DOCUMENT HAS BEEN REPRODUCED FROM THE BEST COPY FURNISHED US BY THE SPONSORING AGENCY. ALTHOUGH IT IS RECOGNIZED THAT CERTAIN PORTIONS ARE ILLEGIBLE, IT IS BEING RELEASED IN THE INTEREST OF MAKING AVAILABLE AS MUCH INFORMATION AS POSSIBLE.

ECASTAR .

Energy Conservation : an Assessment of  
Systems, Technologies And Requirements

BY

AUBURN UNIVERSITY ENGINEERING SYSTEMS DESIGN

SUMMER FACULTY FELLOWS

FINAL REPORT

Prepared Under Grant Number NGT 01-003-044-

UNIVERSITY AFFAIRS OFFICE HEADQUARTERS  
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

with partial funding from

ENERGY CONSERVATION AND ENVIRONMENT  
FEDERAL ENERGY ADMINISTRATION

and

with the cooperation of

THE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

and

SCIENCE AND ENGINEERING  
GEORGE C. MARSHALL SPACE FLIGHT CENTER  
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Reginald I. Vachon  
Professor, Auburn University  
Director

Russell E. Lueg  
Professor, University of Alabama  
Associate Director

William R. Humphries  
Structures and Propulsion  
Laboratory - NASA  
Co-Director

J. Fred O'Brien, Jr.  
Associate Director  
Engineering Extension Service  
Auburn University  
Administrative Director

SEPTEMBER, 1975

*if*



## List of Report Contributors

### Summer Faculty Fellowship Program Auburn University Engineering Systems Design 1975

#### Participating Fellows

Dr. Harvey S. Bierenbaum  
College of Engineering  
University of South Florida

Dr. Roger A. Crane  
College of Engineering  
University of South Florida

Dr. John T. Dunlap  
Department of Philosophy  
Columbus College

Dr. Marie G. Hankins  
University of Evansville

Dr. Warren M. Hankins  
Chemistry Department  
University of Evansville

Dr. Bruce E. Johansen  
Electrical Engineering Department  
Ohio Northern University

Dr. W. Carroll Johnson  
Industrial Engineering Department  
Texas A&M University

Dr. Naim A. Kheir  
Electrical Engineering Department  
University of Alabama in Huntsville

Dr. Thomas R. Lalk  
Department of Mechanical Engineering  
The Cooper Union

Dr. John C. Martin  
Electrical and Computer Engineering  
Department  
Clemson University

Dr. William P. Moran  
Department of Physics  
University of Tulsa

Mr. Jeffrey H. Morehouse  
Department of Mechanical Engineering  
Auburn University

Dr. Charles M. Overby  
Industrial and Systems Engineering  
Ohio University

Mr. Albert Pedulla  
College of Architecture and Environmental Design  
Texas A&M University

Dr. Heriberto Plaza  
Nuclear Engineering  
University of Puerto Rico

Dr. Paul Rappoport  
Department of Economics  
Temple University

Dr. James R. Smith  
Industrial Engineering Department  
Tennessee Technological University

Dr. John A. Sorrentino, Jr.  
Department of Economics  
Temple University

Dr. George H. Stickney  
Mechanical and Aerospace Engineering  
Department  
University of Missouri-Columbia

Dr. John W. Williamson  
Department of Mechanical Engineering  
Vanderbilt University

Mr. Edmund R. Young  
Department of Architecture  
Iowa State University

#### Technical and Administrative Staff

Dr. Reginald I. Vachon  
Department of Mechanical Engineering  
Auburn University

Dr. Russell E. Lueg  
Department of Electrical Engineering  
University of Alabama

Dr. William R. Humphries  
Structures and Propulsion  
Laboratory - NASA  
Marshall Space Flight Center

Mr. J. Fred O'Brien  
Engineering Extension Service  
Auburn University

## GUEST SPEAKERS AND OTHER CONTRIBUTORS

### Guest Speakers

#### U. S. GOVERNMENT

Dr. Douglas Alexander  
Ames Research Center

Dr. Joseph F. Coates  
Office of Technology Assessment

Dr. George Cunningham  
Energy Research and Development Adm.

Dr. Barry Hyman  
Office of Technology Assessment

Mr. Robert Metke  
Tennessee Valley Authority

Mr. Roger Sant  
Federal Energy Administration

Dr. Jack E. Snell  
National Bureau of Standards

Dr. Larry Stewart  
Energy Research and Development Adm.

Mr. Richard Wood  
NASA/Ames

#### NASA HEADQUARTERS

Mr. Stephen L. Copps  
Director of Systems Analysis Div.

Mr. Phil Compton  
Program Manager, Energy Systems for  
Buildings

#### MARSHALL SPACE FLIGHT CENTER

Dr. Donald Bowden  
Project Engineer  
Solar Heating and Cooling Program

Mr. J. N. Foster  
Deputy Director, Administration  
and Program Support

#### INDUSTRY

Mr. Walter Baker  
Alabama Power Company

Mr. Alan Barton  
Alabama Power Company

Mr. Sam Booker  
Alabama Power Company

Mr. Bud Brown  
E. I. DuPont Company

Mr. W. R. Finger  
Exxon Company, U.S.A.

Mr. Bill Keith  
Alabama Power Company

Mr. David J. MacFadyen  
Technology & Economics, Inc.

Mr. Anthony J. Parisi  
Business Week

Mr. Vernon A. Rydbeck  
General Electric Company

Dr. Arnold E. Safer  
Irving Trust Company

Mr. Walter F. Spiegel  
W.F. Spiegel, Inc.

Dr. Stan Trumbower  
Westinghouse Electric Corporation

Mr. Arnold L. Windman  
Syska and Hennessy, Inc.

#### JOHNSON SPACE CENTER

Dr. Story Musgrave  
Scientist-Astronaut

## INSTITUTES, ASSOCIATIONS AND SOCIETIES

Mr. John Eberhard  
AIA Research Company

Dr. Wilson Harwood  
Stanford Research Institute

Mr. Sydney Howe  
Center for Growth Alternatives

Mr. William P. Miller, Jr.  
ASME Washington Representative

Mr. Tim Nulty  
United Auto Workers

Dr. Ralph Rotty  
Institute for Energy Analysis

Mr. Grant P. Thompson  
Environmental Law Institute

## CITIZEN GROUP

Ms. Virginia Garrett  
Montgomery Citizen's Action  
Committee

## UNIVERSITIES

Dr. Laura Nader  
University of California

Dr. William Prengle, Jr.  
University of Houston

Dr. S. T. Wu  
University of Alabama in Huntsville

Dr. John Vanston  
University of Texas

## STATE OF ALABAMA

Mr. John Blackstone  
Economist

Mr. Ed Hudspeth  
Energy Management Board  
Alabama Development Office

Mr. Bill Russell  
Public Television, Montgomery

OTHER CONTRIBUTORS  
(Oral and Written Communications)

MARSHALL SPACE FLIGHT CENTER

Mr. J. N. Foster  
Mr. James Hankins  
Mr. Joe Jones  
Mr. Richard Smith

ASEE

Mr. Tim Bradley

REDSTONE SCIENTIFIC INFORMATION CENTER

Mr. Jim Clark

INDUSTRY

Mr. Don Adams  
Garrett Research and Development

Dr. Bill Bartel  
Occidental Oil Shale Corporation

Mr. Larry Beaulaurier  
Bechtel

Mr. Irv Bevis  
Proctor and Gamble

Dr. Wendall J. Biermann  
Carrier Corporation

Mr. Max Blanchet  
Pacific Gas and Electric Company

Mr. Ray Broadway  
Carolina Power and Light Company

Mr. Nathan Condit  
Libby, Owens, Ford, Incorporated

Ms. Cosos  
Morgan Guaranty

Mr. A. J. D'Arcy  
General Electric Company

Mr. Paul Debaldo  
International Business Machines

Mr. David A. Gruelish  
Manager of Special Projects  
Reynolds Securities, Incorporated

Mr. Dick Guerrin  
Shell Oil Company

Mr. Adel Hakki  
Gordian Associates, Inc.

Mr. Bob Hammons  
Braniff International

Mr. Don Heyburn  
Babcock and Wilcox

Mr. R. A. Huse  
New Jersey Public Service and Gas Co.

Mr. Ned Landon  
General Electric Company

Mr. Chet Lasher  
Pittsburgh Plate Glass

Mr. Arthur P. Lien  
Technology Transfer Associates

Mr. David Littmann  
Manufacturers National Bank of Detroit

Mr. Bill Lueckel  
United Technology

Mr. Harold Lyda  
Real Estate Insider Weekly

Mr. Eugene Nesselson  
Waste Management, Incorporated

Mr. Leon Nvital  
General Electric Company

Mr. R. S. Paul  
Union Carbide Corporation

Mr. Bill Podolny  
United Aircraft Corporation

Mr. Gordon Pye  
Irving Trust Company

Mr. Dick Ridley  
Occidental Oil Shale Corporation

Mr. Ron Schessler  
Union Carbide Corporation

Dr. Thomas R. Schneider  
Public Service Electric and Gas Co.

Mr. H. K. Shannahan  
Electric Energy Association

Mr. Dale Smart  
Dale Smart Trucking Company

Mr. Don Thornburgh  
Alabama Power Company

Mr. Jack Tully  
Combustion Engineering

Mr. Jim Vigani  
Foster Wheeler

Mr. Carl Weinberg  
Pacific Gas and Electric Company

Mr. A. Weiss  
Natural Gas Pipeline Company

Mr. R. S. Wishard, Jr.  
Union Carbide Corporation

## FOUNDATIONS, INSTITUTES, SOCIETIES, AND ACADEMIES

Mr. Phil Beaum  
American Public Transit Association

Ms. Susan Cook  
U. S. Travel Data Center

Dr. Robert Crow  
Electric Power Research Institute

Mr. Henry Darius  
Electric Power Research Institute

Mr. John Faber  
The National Ash Association

Mr. Arnold Lickett  
Electric Power Research Institute

Dr. John Garner  
Human Studies Laboratory, EPA

Dr. Allen G. Gray  
American Society for Metals

Dr. Jack Hubler  
Research and Development for the  
Institute of Gas Technology

Mr. Perry Kent  
Federal Highway Administration

Mr. Jim Loomis  
Battelle Memorial Institute

Mr. Mike Maaghoul  
Electric Power Research Institute

Dr. H. Majmudar  
Worcester Polytechnic Institute

Mr. Fred Mascey  
NASA/Ames Research Center

Mr. Pat McCue  
American Association of Railroads

Mr. Ken Mowell  
Systems Design Concepts, Inc.

Mr. E. R. Perry  
Electric Power Research Institute

Mr. John Reith  
American Trucking Association, Inc.

Mr. Ed Robinson  
Air Transportation Association

Mr. Richard L. Rudman  
Electric Power Research Institute

Mr. Robert Sandberg  
Electric Power Research Institute

Mr. Sam H. Schurr  
Electric Power Research Institute

Mr. Ed Star  
Engineer's Joint Council

Mr. Lloyd Trimble  
Lockheed Oceans Systems

Mr. Paul Wagner  
Edison Electric Institute

Mr. Jack Young  
Edison Electric Institute

Mr. Durwood Zaelke  
Environmental Law Institute

## OTHER GOVERNMENT AGENCIES

Mr. Peter Back  
Federal Energy Administration

Office of Congressman William Barrett

Mr. Jack Belding  
Energy Research and Development Adm.

Ms. Gay Bennethum  
Department of Interior

Mr. Sidney Berwager  
Federal Energy Administration

Mr. Milton Brooks  
Urban Mass Transit Authority

Mr. Robert Cohen  
Energy Research and Development Adm.

Mr. J. Constantz  
Civil Aeronautics Board

Mr. Lou Divone  
Solar, Geothermal and Advanced Energy  
Systems of ERDA

Mr. Larry Falick  
Energy Research and Development Adm.

Mr. Ron J. Fisher  
Office of Transit Planning

Mr. Bob Forte  
Office of Congressman Jack Brinkley

Mr. Kline Fraser  
Department of Transportation

Mr. Earle Gavett  
USDA - ERS

Dr. Richard Grote  
National Bureau of Standards

Ms. Joy Guthrie  
National Petroleum Council

Mr. Walter Harriott  
Department of Transportation

Mr. Bill Hemphill  
Federal Energy Administration

Dr. Jean Henschel  
Energy Research and Development Adm.

Mr. Phinens Indritz  
House Subcommittee on Energy and  
Power

Mr. Lambert Irons  
Federal Aviation Administration

Mr. Rick Jones  
Energy Policy Project

Mr. Bill Johnson  
NASA/Lewis

Mr. Harry Johnson  
Department of Interior

Dr. James Joubert  
Energy Research and Development Adm.

Mr. Bill Klassen  
Office of Highway Planning

Ms. Sue Lauffer  
Department of Transportation

Mr. Bob Lowe  
Environmental Protection Agency

Mr. Larry Mabry  
Federal Energy Administration

Mr. Ralph Marks  
Office of Deputy Director for  
Research in the Department of Labor

Mr. Milt Meisaer  
Federal Aviation Administration

Mr. Fred Meister  
Federal Energy Administration

Mr. Jim Meyers  
Tennessee Valley Authority

Congressman Clarence Miller  
U. S. Congress

Mr. Mike Miller  
Department of Transportation

Mr. John E. Mock  
Energy Research and Development Adm.

Mr. Dario Monti  
Energy Research and Development Adm.

Mr. Don Morin  
Office of Highway Planning

Office of Senator Hubert Humphrey

Mr. Jack Phillips  
Energy Research and Development Adm.

Mr. Carl M. Podeweltz  
Tennessee Valley Authority

Dr. Joe Porona  
Energy Research and Development Adm.

Mr. Richard Porter  
Board of Governors of the Federal  
Reserve System

Mr. William Porter  
Federal Energy Administration

Mr. Davis A. Portner  
U. S. Department of Labor

Dr. Tom Pretorius  
Energy Research and Development Adm.

Ms. Diane Purkey  
Federal Energy Administration

Mr. Stephen S. Rappoport  
Bureau of National Affairs

Mr. Ed Reinse  
U. S. Department of Agriculture

Mr. Dick Schmidt  
Electric Power Research Institute

Mr. John Scholes  
NASA/Lewis

Mr. W. J. Sherrard  
Florida Energy Office

Ms. Patricia Spencer  
U. S. Department of Commerce

Mr. Mayo Stuntz  
Federal Energy Administration

Mr. Gary Timm  
Environmental Protection Agency

Dr. Ken Tyree  
Bureau of Labor Statistics

Mr. Morey Williamson  
Energy Research and Development Adm.

## UNIVERSITIES

Mr. Jim Benson  
Texas A&M University

Dr. Thadís Box  
Utah State University

Dr. Clark Bullard  
Center for Advanced Computation  
University of Illinois

Dean Ralph Fadum  
North Carolina State University

Dr. M. J. Fox  
Texas A&M University

Mr. Donald J. Grace  
University of Hawaii

Mr. Jack Lamkin  
Texas A&M University

Dr. Howard Odum  
University of Florida

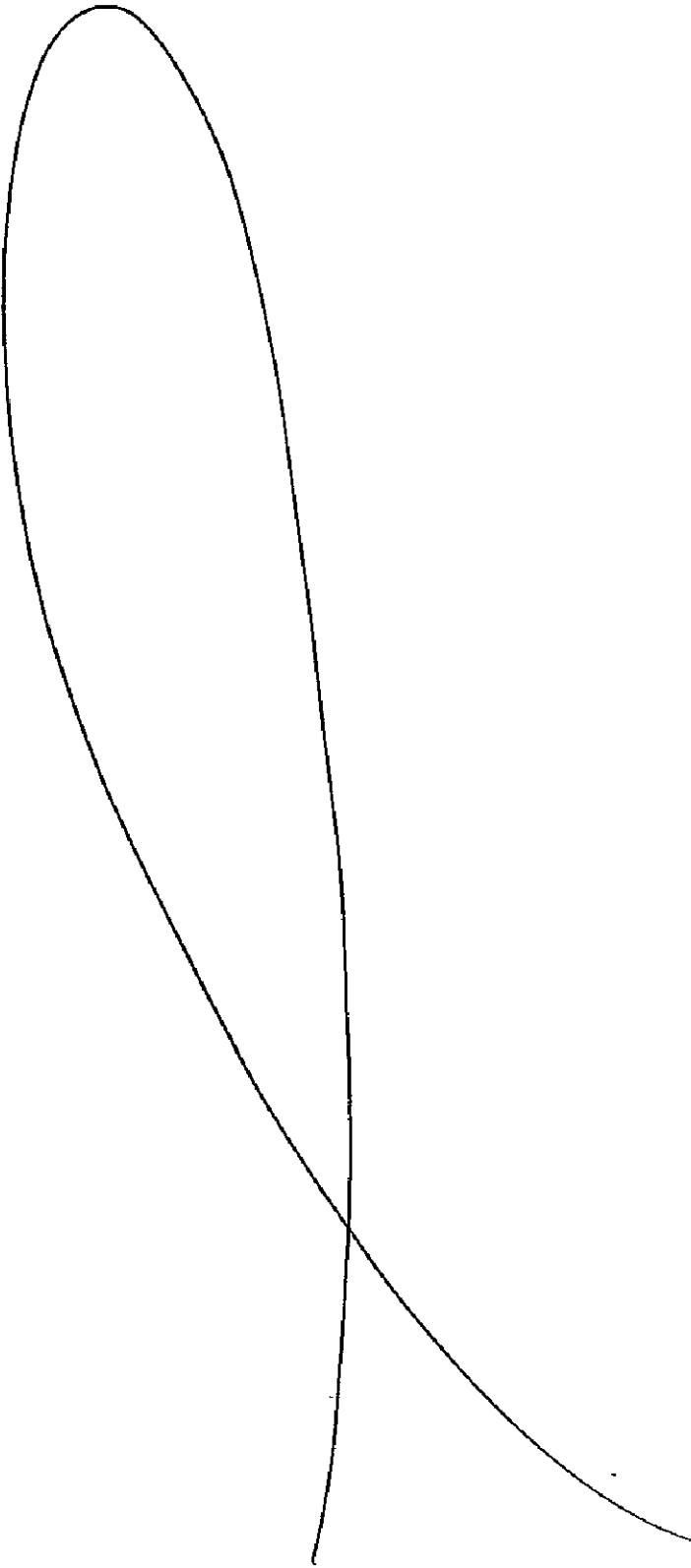
Ms. Carolyn Sawyer  
University of Alabama

Mr. Robert Skolow  
Center for Environmental Studies  
Princeton University

Professor Chuck Sepsy  
Ohio State University

Dr. Virgil Stover  
Texas A&M University

Mr. Fred Strawbridge  
Temple University



## ABSTRACT

ECASTAR presents a methodology for a systems approach display and assessment of the potential for energy conservation actions and the impacts of those actions. The U. S. economy is divided into four sectors -- energy industry, industry, residential/commercial and transportation. Each sector is assessed with respect to energy conservation actions and impacts. The four sectors are combined and three strategies for energy conservation actions for the combined sectors are assessed. The three strategies (national energy conservation, electrification and diversification) represent energy conservation actions for the near term (now to 1985), the mid term (1985 to 2000) and the far term (2000 and beyond). The assessment procedure includes input/output analysis to bridge the flows between the sectors, and net economics and net energetics as performance criteria for the conservation actions. The abbreviated 30 x 30 input/output analysis matrix developed in ECASTAR relates dollars, BTU's and labor to total industrial production. The matrix is thought to be the ideal size for energy policy analysis. A feature of the assessment methodology is the identification of targets of opportunity for large net energy savings and the application of technology to achieve these savings. In addition, citizen's actions for energy conservation are discussed.

ECASTAR represents the result of an educational effort in systems approach methodology. Thus ECASTAR presents a display of energy conservation as seen by the participants who initially lacked detailed background in the energy area.

**PRECEDING PAGE BLANK NOT FILMED**



## TABLE OF CONTENTS

LIST OF PARTICIPANTS AND STAFF . . . . .	ii
GUEST SPEAKERS AND OTHER CONTRIBUTORS . . . . .	iii
ABSTRACT . . . . .	ix
TABLE OF CONTENTS . . . . .	x
ACKNOWLEDGMENTS . . . . .	xiv
INTRODUCTION . . . . .	xvi
CHAPTER 1. THE POLITICAL ECONOMY OF CONSERVATION . . . . .	1-1
1.1. INTRODUCTION . . . . .	1-1
1.2. ENERGY ECONOMICS . . . . .	1-1
1.3. THE ROLE OF GOVERNMENT . . . . .	1-10
1.4. CONSERVATION ACTION-IMPACT FLOW . . . . .	1-10
CHAPTER 2. CONSERVATION: TOWARD FIRMER GROUND . . . . .	2-1
2.1. CONSERVATION HISTORY AND GOALS . . . . .	2-1
2.2. CONSERVATION MODES . . . . .	2-3
2.3. CONSERVATION ACCOUNTING - CRITERIA . . . . .	2-5
2.4. A METHOD TO OVERCOME OBSTACLES . . . . .	2-8
CHAPTER 3. ECSTAR SYSTEMS APPROACH . . . . .	3-1
3.1. THE METHOD . . . . .	3-1
3.2. APPLYING THE METHOD . . . . .	3-6
3.3. INPUT-OUTPUT ANALYSIS . . . . .	3-17
3.4. ENERGY PERFORMANCE CRITERIA: NET ENERGETICS VERSUS NET ECONOMICS . . . . .	3-20
3.5. AN EXAMPLE OF THE METHOD: TECHNOLOGY APPLICATION . . . . .	3-27
CHAPTER 4. CONSERVATION IN THE ENERGY INDUSTRY . . . . .	4-1
4.1. INTRODUCTION . . . . .	4-1
4.2. CONSERVATION STATUS . . . . .	4-2
4.3. GOVERNMENT CONSERVATION STATUS . . . . .	4-4
4.4. ACTIONS . . . . .	4-4
4.5. THE GOVERNMENT DEREGULATES NATURAL GAS PRICES . . . . .	4-9
CHAPTER 5. CONSERVATION AND THE INDUSTRY SECTOR . . . . .	5-1
5.1. INTRODUCTION . . . . .	5-3
5.2. CONSUMPTION STATUS . . . . .	5-4
5.3. CONSERVATION STATUS IN INDUSTRY . . . . .	5-4

## TABLE OF CONTENTS (Continued)

5.4.	GOVERNMENT ACTIONS . . . . .	5-7
5.5.	CONSERVATION ACTIONS . . . . .	5-7
5.6.	ASSESSMENT AND IMPACTS . . . . .	5-11
CHAPTER 6.	ENERGY CONSERVATION AND THE TRANSPORTATION SECTOR . . . . .	6-1
6.1.	INTRODUCTION . . . . .	6-1
6.2.	TOTAL ENERGY USE IN TRANSPORTATION . . . . .	6-5
6.3.	CONSERVATION STATUS . . . . .	6-10
6.4.	GOVERNMENT ACTION STATUS . . . . .	6-11
6.5.	SELECTED CONSERVATION ACTIONS . . . . .	6-12
CHAPTER 7.	ENERGY CONSERVATION AND THE RESIDENTIAL AND COMMERCIAL SECTOR . . . . .	7-1
7.1.	INTRODUCTION . . . . .	7-2
7.2.	CONSUMPTION STATUS . . . . .	7-4
7.3.	CONSERVATION STATUS . . . . .	7-4
7.4.	GOVERNMENT ACTION STATUS . . . . .	7-11
7.5.	SELECTED CONSERVATION ACTIONS . . . . .	7-13
7.6.	ASSESSMENTS . . . . .	7-21
CHAPTER 8.	INPUT-OUTPUT ANALYSIS OF SOME SECTOR ACTIONS . . . . .	8-1
8.1.	INTRODUCTION . . . . .	8-1
8.2.	THE ECASTAR ENERGY INPUT-OUTPUT MODEL . . . . .	8-2
8.3.	THE BASE CASE . . . . .	8-4
8.4.	ACTIONS . . . . .	8-6
8.5.	SUMMARY . . . . .	8-15
CHAPTER 9.	NATIONAL ENERGY CONSERVATION . . . . .	9-1
9.1.	INTRODUCTION . . . . .	9-1
9.2.	DISCUSSION OF ACTIONS . . . . .	9-8
9.3.	INPUT-OUTPUT ANALYSIS OF NATIONAL ENERGY CONSERVATION . . . . .	9-25
CHAPTER 10.	ELECTRIFICATION . . . . .	10-1
10.1.	INTRODUCTION . . . . .	10-1
10.2.	ENERGY INDUSTRY ACTIONS . . . . .	10-2
10.3.	ACTIONS IN OTHER SECTORS . . . . .	10-16
10.4.	CONSERVATION FEEDBACK AND IMPACTS . . . . .	10-19
10.5.	RECOMMENDATION . . . . .	10-22
CHAPTER 11.	DIVERSIFICATION OF ENERGY SOURCES . . . . .	11-1
11.1.	DEFINITION AND BACKGROUND . . . . .	11-1
11.2.	THE SYSTEMS APPROACH TO DIVERSIFICATION . . . . .	11-3
11.3.	ADVANTAGES, CRITERIA, AND CONSTRAINTS . . . . .	11-5
11.4.	CURRENT STATUS AND PREVAILING VIEWS OF DIVERSIFICATION . . . . .	11-9
11.5.	MEANS OF IMPLEMENTATION . . . . .	11-11
11.6.	ACTIONS . . . . .	11-12
11.7.	ASSESSMENTS . . . . .	11-13

## TABLE OF CONTENTS (Continued)

CHAPTER 12. CITIZENS' ACTIONS . . . . .	12-1
12.1. BACKGROUND . . . . .	12-2
12.2. OIL EMBARGO AND THE CONSUMER . . . . .	12-7
12.3. BARRIERS TO SAVINGS . . . . .	12-8
12.4. INCENTIVES TO SAVE . . . . .	12-10
12.5. PRESENT APPROACHES . . . . .	12-11
12.6. SAVINGS -- POTENTIAL AND PROGRAMS . . . . .	12-14
12.7. CONCLUSION AND RECOMMENDATIONS . . . . .	12-16
CHAPTER 13. ECASTAR SUMMARY AND RECOMMENDATIONS . . . . .	13-1
13.1. UNRESOLVED ISSUES . . . . .	13-2
13.2. RECOMMENDATIONS . . . . .	13-7
13.3. EPILOGUE . . . . .	13-13
APPENDIX A. ABBREVIATIONS . . . . .	A-1
APPENDIX B. UNITS AND CONVERSION FACTORS . . . . .	B-1
B.1. ENERGY UNITS . . . . .	B-1
B.2. POWER PLANT RATINGS . . . . .	B-1
APPENDIX C. ALTERNATE ENERGY PERFORMANCE CRITERIA . . . . .	C-1
C.1. EFFICIENCY CRITERIA . . . . .	C-1
C.2. IMPLEMENTATION OF PERFORMANCE CRITERIA . . . . .	C-11
C.3. APPLICATION OF THE CRITERIA TO MAJOR ISSUES . . . . .	C-16
C.4. CRITERIA APPLIED TO A HELIOSTAT SOLAR PLANT . . . . .	C-23
APPENDIX D. REPORT OF THE ENERGY INDUSTRY TASK GROUP . . . . .	D-1
D.1. INTRODUCTION . . . . .	D-1
D.2. PRESENT ENERGY SYSTEMS . . . . .	D-1
D.3. DEVELOPING ENERGY SYSTEMS . . . . .	D-40
D.4. GENERAL PROPOSED ACTIONS . . . . .	D-68
APPENDIX E. CONSERVATION AND THE INDUSTRY SECTOR . . . . .	E-1
E.1. INTRODUCTION . . . . .	E-1
E.2. INDUSTRY ENERGY CONSERVATION . . . . .	E-11
E.3. CONSERVATION STATUS . . . . .	E-23
E.4. GOVERNMENT ACTIONS . . . . .	E-42
E.5. ACTIONS . . . . .	E-46
APPENDIX F. A STUDY OF ENERGY CONSERVATION IN THE TRANSPORTATION SECTOR . . . . .	F-1
F.1. METHOD ADOPTED . . . . .	F-1
F.2. CONSTRAINTS AND CRITERIA . . . . .	F-4

## TABLE OF CONTENTS (Continued)

F.3.	POSSIBLE ENERGY CONSERVATION ACTIONS IN THE TRANSPORTATION SECTOR AND THEIR POTENTIAL . . . . .	F-4
F.4.	ASSESSMENT OF ACTIONS . . . . .	F-12
F.5.	SOME VIEWS TO THE FUTURE . . . . .	F-26
F.6.	ENERGY ENVELOPE CURVES FOR THE TRANSPORTATION SECTOR . . . . .	F-35
APPENDIX G. CONSERVATION IN THE RESIDENTIAL AND COMMERCIAL SECTOR . . . . .		G-1
G.1.	INTRODUCTION . . . . .	G-1
G.2.	REDUCING CONSUMPTION AND INCREASING EFFICIENCY OF BUILDINGS . . . . .	G-20
G.3.	RESIDENTIAL/COMMERCIAL SUBSTITUTION ACTIONS . . . . .	G-42
G.4.	RESIDENTIAL/COMMERCIAL -- REDUCE ENERGY USE IN LIGHTING IN COMMERCIAL SECTOR . . . . .	G-75
G.5.	RESIDENTIAL/COMMERCIAL REDUCED CONSUMPTION AND INCREASED EFFICIENCY OF RESIDENTIAL HOT WATER SYSTEMS . . . . .	G-92
APPENDIX H. ECASTAR ENERGY INPUT-OUTPUT MODEL . . . . .		H-1
APPENDIX I. NATIONAL ENERGY CONSERVATION DATA . . . . .		I-1
I.1.	ACTIONS 1 AND 3 TABLES AND FIGURES . . . . .	I-1
I.2.	ACTION 6 -- CONVERSION FROM OIL OR GAS TO OTHER FUELS . . . . .	I-1
APPENDIX J. ELECTRIFICATION . . . . .		J-1
J.1.	INTRODUCTION . . . . .	J-1
J.2.	ENERGY INDUSTRY ACTIONS . . . . .	J-1
J.3.	ACTIONS IN OTHER SECTORS . . . . .	J-49
APPENDIX K. DIVERSIFICATION . . . . .		K-1
K.1.	DIVERSIFICATION ACTIONS . . . . .	K-1
K.2.	REQUIREMENTS FOR DIVERSIFICATION WATER IMPACT STUDY . . . . .	K-10
K.3.	ASSESSMENT OF ENERGY SOURCE IMPACTS IN WATER SCARCE REGIONS . . . . .	K-21
K.4.	ERDA PLANS AND BUDGET . . . . .	K-24
APPENDIX L. CITIZENS' ACTIONS . . . . .		L-1
APPENDIX M. SEMINAR SUMMARIES . . . . .		M-1
APPENDIX N. FEDERAL AND STATE ENERGY LEGISLATION . . . . .		N-1
N.1.	FEDERAL ENERGY-RELATED LEGISLATION . . . . .	N-2
N.2.	STATE ENERGY-RELATED LEGISLATION . . . . .	N-13
REFERENCES		

## ACKNOWLEDGMENTS

The successful completion of ECASTAR would not have been achieved without the unstinting support of the many offices and personnel of the Marshall Space Flight Center as well as the many people from private industries, universities, the Federal Government, utilities, institutes, etc., who provided valuable resource material via seminars, telephone conversations and written communications. It is not possible to give proper recognition to all of the individuals who participated in our program; however, we have listed certain speakers and others who contributed substantially to the ECASTAR effort. These contributors are listed in the front portion of this report and summaries of the speakers' remarks are given in Appendix M.

We wish to express our thanks to Dr. W. R. Lucas, Director of MSFC; Mr. R. G. Smith, Deputy Director; Mr. J. S. Potate, Associate Director; Col. E. O. Mohlere, Assistant to the Director; Dr. Ernst Stuhlinger, Associate Director for Science; and especially to Dr. George Bucher, Deputy Associate Director for Science; Dr. Randy Humphries, our NASA Co-Director deserves our particular appreciation.

Mr. J. T. Shepherd, Mr. J. N. Foster, Mr. J. R. Johnson, Mr. Jim Dowdy, Mr. Bob Francis, Mr. Bob Wessels, Mr. S. J. Sweat, Mr. David Pughe, Mr. Brian Pitre and many others deserve credit and appreciation for providing the physical facilities and supplies. Mr. Clyde Hightower gave his enthusiastic and invaluable support throughout the summer and we say, "thank you" for the many things he did for the group.

The success of any program depends on the resource material that is made available to the participants. The NASA Regional Information Center and the Redstone Scientific Information Centers are run by dedicated, capable and helpful librarians. These two centers have, over the years, provided excellent support to the NASA/ASEE programs and we sincerely appreciate the efforts of all of the professionals who assisted us, especially Ms. Charlotte Dabbs of NASA and Mr. Jim Clark of RSIC.

The office of Public Affairs has answered many requests during the program and we thank Mr. Joe Jones, Mr. Guy Jackson, Mr. Ed Schorston and Ms. Vivian Whitely, Mr. Bill Mayes, and Mr. Curtis Hunt.

Mr. Bill Chandler and Mr. Dean Cagle of Graphic Engineering and Mr. Ron Cook and Mr. George Wertz of Hayes International provided us with much needed support by providing the figures and art work that were often needed on a rush basis. Mr. Charles Allen of the Photo Lab provided similar support of our photographic needs. Without their cooperation,

## INTRODUCTION

Within the eleven week ECASTAR fellowship program, systems analysis has been applied to the important topic of energy conservation. It must be noted that much of the worth of the ensuing document is based on the method of analysis. The ECASTAR group, of course, could not have generated a numerical analysis comparable to Project Independence and other important studies relating to conservation. The hope is that the ECASTAR characterization will cause policymakers to have a broad perspective when deciding on conservation actions.

The reader will find Chapter 1 to present a discussion of the political economy of the U. S. It is felt that it is necessary in the systems approach to introduce the reader to the subject matter initially at this level of generality. Chapter 2, then, leads the reader into the group's struggle to characterize conservation. It should be noted that one conclusion reached is that conservation cannot be defined in absolute terms.

In Chapter 3, the methods of analysis used in the study are presented. Some of these tools are traditional while others are somewhat innovative. Most useful in general is the systems approach itself. Input-output analysis and "net energetics" are useful in specific problems.

Chapters 4 through 7 discuss the work of the task groups broken down into the energy industry, industry, transportation, and residential/commercial sectors. Data is given here to describe the state of the world in these sectors, and action-impact discussion not necessarily related to the broader issues of Chapters 9, 10, 11, and 12 is found here. Chapter 8 represents a reconciliation of the task group analysis in terms of overall constraints and criteria, impacts and their implications for conservation action trade-offs. This again is part of the essence of systems analysis.

As mentioned, Chapters 9-12 discuss several broad issues of the day in terms of conservation. These general actions are divided into their requisite subactions, and the latter are carried through the impact analysis. Some general comments and recommendations regarding the overall action are presented.

Chapter 13 gives a summary of the work and some recommendations the group posits as a result of the summer study. It should again be noted that these recommendations are far from absolute. In the spirit of the systems approach, they should be reconciled with comparable studies around the nation.

The ECASTAR study closes with a set of appendices which either enlarge upon the discussion, present material not contained, or list things that would be cumbersome in the text itself.

our final report and final presentation simply could not have been completed in a proper fashion.

Mr. W. J. Ziak, Mr. C. Kelley Brown and Mr. Bill Ziegler deserve a word of special praise for reproducing the interim reports in record time. Mr. Roy Marcato helped us with the final presentation in Morris Auditorium. Mr. Ivan Krivutza provided a copying system for rapid turn-around on our documents and this system helped immeasurably.

We thank Mr. Jim Ledbetter, Mr. Jake Levie, Mr. Stan Fragge and Mr. Dan Ahlander for their help and assistance.

The continued support and funding of these summer programs are due to Dr. Frank Hansing and Mr. Charles Carter of the Office of University Affairs at NASA Headquarters. Mr. Hansing and Mr. Carter, along with Mr. Francis X. Bradley of ASEE Headquarters, and their many associates, certainly deserve recognition by the education community for their sustained efforts in providing programs that are of great benefit to educators, NASA, and society in general.

This year the program was partially funded by the Federal Energy Administration. We appreciate the confidence that Mr. Roger Sant, Assistant Administrator FEA and Dr. Bill Wortham of Mr. Sant's office expressed by their support of the effort.

The assistance of the many MSFC administrative assistants and secretaries is appreciated. Ms. R. Barnes, program secretary, and Ms. Susan Edwards, staff secretary, provided invaluable support throughout the summer. In addition, the following did an outstanding job of typing at one time or another on the interim and/or final reports: Janis M. Averyt, Rosemary Barnes, Audra G. Clark, Cora Edwards, Vicky Danby, Susan G. Edwards, Jeannie L. Galey, Sharon Grimes, Beverly Kipp, Joy E. Moody, Barbara O'Guin, Martha L. Parsons, Bonita K. Pearson, Linda B. Putnam, Wanda L. Norton, Karan L. Sharp, Sally Sharp, Pat Southerland, Patricia A. Wallace, Amy J. Strickland, Katherine Williams.

We also appreciate the fine work done by Barbara McClinton and Nancy Creal at Auburn University during the typing and proofing of the final report.

We thank all of you.

It might also be said that ECASTAR is a response to a statement made by Congressman McCormack in his opening statement to a joint session of the Conservation and Natural Resources Subcommittee of the Committee on Government Operations, and Energy subcommittee of the Committee on Science and Astronautics (June 9, 1973):

Needless to say, this [i.e. energy conservation] is a very broad topic, and includes more than just turning off light bulbs and riding bicycles to the corner store. It also means taking a systems approach to our Nation's energy requirements. It means improving the efficiency of energy conversion, transmission, and utilization. It means implementing policies at the national and local levels that will encourage all of our citizens to conserve energy to the maximum extent feasible.

\* \* \*

The following is a contrived discussion between the ECASTAR Group (G) and a ninefold composite of the myriad of speakers and other persons contacted during the summer. The speakers are characterized by the following titles, which by no means are meant to reflect any particular persons encountered:

AT: The Advanced Technologist

AD: The Ankle Deeper

CE: The Consulting Engineer

D: The Diversifier

E: The Electrifier

GB: The General Businessman

KD: The Knee Deeper

NP: The Nuclear Powerite

PP: The People Person.

The conversation touched on many important areas and gave the group much of the impetus for the sequel. The key questions asked by the group are emphasized in order to outline the important areas discussed below.

The discontinuity between some of the questions and their answers is done purposely. Often the speakers would not directly address certain issues, but would sneak up on or around the question. However, all questions asked, in the sequel below, ultimately get some sort of answer.



## DIALOGUE

- G. It appears that the U. S. is in a somewhat difficult energy situation. How do you think it can deal with its increasing reliance on foreign oil supplies? They are approaching 40% of our domestic consumption.
- E. We should use coal and nuclear power to generate electricity! What else?
- D. Not only those! They are only part of the Energy Research and Development Administration's plan to explore all of America's energy options. These include oil shale, solar, geothermal, wind, liquified and gasified coal, etc.
- G. SHOULD WE EMPLOY CONSERVATION BY SUBSTITUTING PLENTIFUL FOR SCARCE ENERGY RESOURCES?
- PP. I think we should stop our wasteful and imprudent consumption. That is, simply curtail our use of gasoline, heating oil and other products.
- G. SHOULD WE EMPLOY CONSERVATION BY CURTAILING END USE OF ENERGY?
- CE. All of this may be true, but I think that all energy consumers can use less energy if they would implement more efficient technology.
- G. SHOULD WE EMPLOY CONSERVATION BY INCREASING THE EFFICIENCY OF ENERGY-USING DEVICES?
- KD. I don't know why you are worried about conservation. Let's think of the Organization of Petroleum Exporting Countries (OPEC). They have joined together to wield monopoly power. But, since prices are rising, the demand for oil in the consuming nations is going down and domestic supplies are going up. The world is in danger of being flooded with crude oil in a few years. The OPEC nations will no longer have the world over the barrel, and we'll be knee-deep in oil!
- AD. That's true, but consider two things. One is that the world's oil supply is finite, and knee-deep in 1980 will mean ankle-deep in 2000 and the end will come soon after. The second is that the Mideast oil producers have accumulated so much wealth that they can hold production down and prices up indefinitely.
- NP. That's why we need the breeder reactor!
- E. Coal-fired power plants also.
- D. Yes, but all of the other sources must be exploited. Also, we should set up an international cooperative of consuming nations to face the OPEC cartel.

G. WILL CONSERVATION BE AN IMPORTANT WAY OF LIMITING OPEC POWER?

AT. We can help with technologies that have been implemented in other areas. We have satellite scanning techniques for resource exploration, telecommunications to replace transportation, more efficient and manageable conducting modes, materials recycling techniques, and even research laboratories outside of the earth's environment. Our technical know-how combined with a long lead time to make these decisions (for we are not on the brink of disaster) make me feel optimistic. Don't think that private industry will let the country go down either. Did you hear that oil companies are buying coal and uranium?

KD. I agree. The energy shortage of 1973-74 was not an energy crisis. There was plenty of oil in the world. It was an economic crisis in a world that had underpaid for fuels for several decades. The problem was that people and firms could not change their ways very rapidly. This caused disruption. In the longer run, adjustment is easier. On the other hand, we may have to adjust to energy prices that are low once again.

PP. Low prices will cause people to resume their wasteful ways. History has a funny way of repeating itself. Besides, this whole oil crisis may have started with a jolt from the Arabs, but it may be an exercise of oil company power here at home. Remember, if you need something strongly, you'll pay nearly any price for it. I heard that oil companies may have decreased gasoline production early this year to create a shortage this summer. That's no surprise, however; it's a rip-off world. Corporations and their members seem ruled by the profit motive run rampant.

GB. All this self-righteousness about wastefulness and the business conspiracy to exploit the consumers. Wastefulness creates jobs. If you change this, you'll disrupt the economy. Also, the conspiracy seems to get the product to the people. Let them try to get these goods without it!

G. DO YOU THINK THAT CONSERVATION WILL HAVE STRONG ECONOMIC IMPACT?

PP. Conservation will probably create more jobs than it destroys.

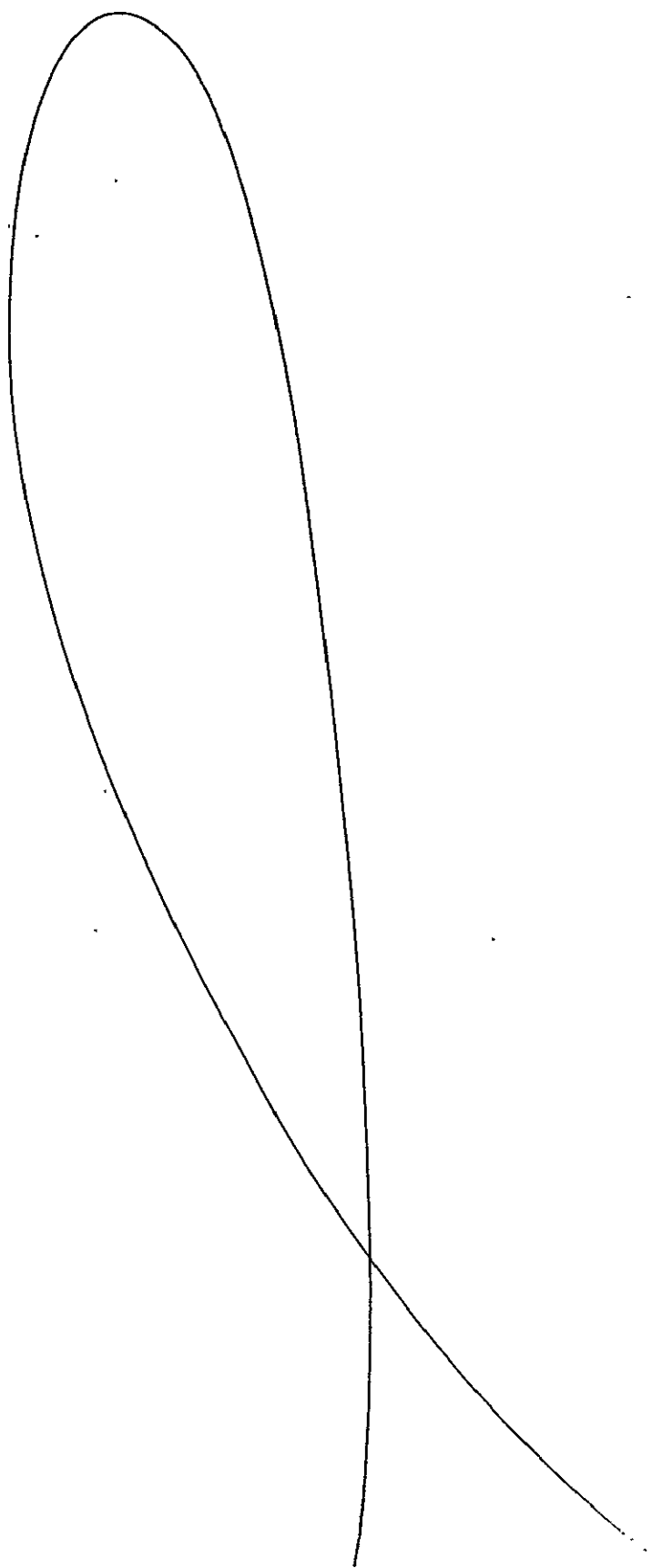
GB. It's anyone's guess. I think that much of the blame for this so-called energy crisis goes to the environmentalists. They wanted too much too soon and now the consumers are paying for it. They stall power plant construction, offshore drilling, strip mining and pipeline construction. For what?

G. WILL THE ENVIRONMENTAL IMPACTS OF CONSERVATION BE SIGNIFICANT?

GB. That may be so, but business is business!

- G. WHAT POLITICAL AND SOCIAL IMPACTS MIGHT WE EXPECT CONSERVATION TO HAVE?
- GB. I don't know, but you can bet that the system will take care of itself.
- G. You mentioned coal and nuclear power earlier. What role do you see them playing from now to 1985?
- D. NATIONAL ENERGY CONSERVATION is currently before the Congress. It proposes that power plants and large industrial oil and gas users that can switch to coal must do so. We know that coal presents some serious environmental problems, but with capital and energy we can solve them.
- G. SHOULD WE USE THE SYSTEMS APPROACH TO FORMULATE NATIONAL ENERGY CONSERVATION POLICY?
- NP & E (in unison). Nuclear power will supply about 20% of total energy by 1985.
- G. Don't you see some problems with this?
- PP. Yes, and I'm glad. First of all, people waste too much and don't need additional electricity in the future. Secondly, the thermal discharge and radioactive waste problems have not been solved. Thirdly, if the breeder reactor ever comes on line, plutonium will endanger a large portion of the population.
- NP. Plutonium is not THAT serious a problem. Do you know anyone who has died from plutonium?
- GB. Don't worry, we will NEVER see the breeder in our lifetimes. In fact, the current nuclear plants are being postponed.
- NP. The country doesn't realize that the energy content of our uranium resources is over four times that of oil, coal and gas. Also, fewer people die from nuclear power than from the other three.
- E. That's right. But strip mined coal is becoming the trend and is less hazardous. Coal along with nuclear will electrify the economy. And, we can plan on the breeder.
- G. IS ELECTRIFICATION A CONSERVATION STRATEGY?
- D. That is yet to be determined. And, remember, it is only part of the ERDA plan to broaden our domestic resource base. We must diversify.

- G. IS DIVERSIFICATION NECESSARILY A CONSERVATION MEASURE?
- G. DO YOU PERCEIVE ANY BOTTLENECKS TO THE IMPLEMENTATION OF NATIONAL ENERGY CONSERVATION, DIVERSIFICATION OR ELECTRIFICATION?
- D. Under different assumptions about what the economy will be like in the future, we get different answers. Hence, we are not sure what bottlenecks may occur.
- PP. Don't any of the leaders of government and industry feel guilty about imposing their will upon the public?
- GB & E (in unison). We give the people what they want!
- D. We need a national policy to guide the decentralized decisions of people and firms. Voluntary conservation actions cannot be relied upon.
- PP. How do you know what is good for society in general?
- D. We deal with many groups with varied objectives. We must assess the actions in terms of the impacts and tradeoffs associated with them. Then, we will make the best decision with the available information.
- PP. What do you think the best decision will be?
- D. WE HOPE THAT THE ECASTAR GROUP CAN HELP US ANSWER THAT QUESTION. . .



### 1.2.1 SUBSTITUTION AND ELASTICITY

Consumers of energy and other goods and services combine these into bundles which act as inputs to their consumption activity. This is schematically shown in Figure 1.2.1-1. The bundle of outputs of the activity is intangible. Based on income and relative prices of energy and other goods and services, the person chooses the best input bundle.

Producers of energy and other goods and services use energy and intermediate goods and services to create their outputs. This is shown in Figure 1.2.1-2. They also choose the best bundle according to their available funds and the prices of their inputs and outputs. The technology of the consuming and producing devices is an important determinant in the choice problem and will be discussed more fully.

Two important notions in the decision-making of both consumers and producers are those of substitution and elasticity. In discussing these, we shall refer to a general decision-maker (DM).

If available funds and/or prices change, the DM will generally change the chosen bundle. Substitution can simply be considered as a choice which replaces some previous choice. In essence, scarcity implies substitutions, and it must be decided at which level they must be made. For example, the DM may substitute energy for material goods or services, energy form for energy form, output for output or smaller amounts of anything for previously larger ones.

Suppose the price of energy is allowed to increase while all other prices and available funds stay constant relative to each other. Since energy has become more expensive, the DM will find other goods and services which lower the amounts of energy used. A firm may use more labor to replace a fuel-related energy-using machine. A consumer may replace a power lawn mower with a manual one.

The degree to which a DM is responsive to changes in prices and available funds is called "elasticity." Price elasticity measures the ratio of a proportional change in quantity to a proportional change in price. Consider the example of a person's weekly consumption of gasoline when the price goes from 50¢ to 60¢ per gallon (see Table 1.2.1-1).

## CHAPTER I. THE POLITICAL ECONOMY OF CONSERVATION

The discussion of Chapter I is concerned with delineating a political economic purview of energy conservation in the United States. The concepts of substitution and elasticity are distinguished, and further distinctions are made between short run price elasticity, cross price elasticity, and available fund elasticity. An assessment of the role which cost factors can play in conservation is given. The structure of the petroleum industry and foreign petroleum resources is discussed. Also discussed is the role of government, industry and the consumer with the economic sphere.

### 1.1 INTRODUCTION

A particularly useful aspect of the systems approach is that nearly every system may be imbedded in a more general system. The "givens" in the smaller system become variables in the larger. The political economy of the U. S. is that system which allocates the resources of society through the forces of the market and decree of the government. The principal agents are: the citizens, suppliers of resources and consumers of final goods and services; the firms, consumers of resources and suppliers of final goods and services; labor unions, protectors of the rights of workers; and the government, the overseer of all and consumer of resources, goods and services. Contained in the system is the technological purview of the researcher and engineer. The political economy takes the psychological and social motivations of the people as constant. Clearly, an even more general system (e.g., anthropological) would consider these as variables.

What we shall consider below as conservation is a part of the overall energy problem. The following sections describe some of the phenomena of political economy which have particular relevance to the conservation analysis undertaken below.

### 1.2 ENERGY ECONOMICS

In this subsection, various economic concepts that appear directly relevant to the energy problem are reviewed.

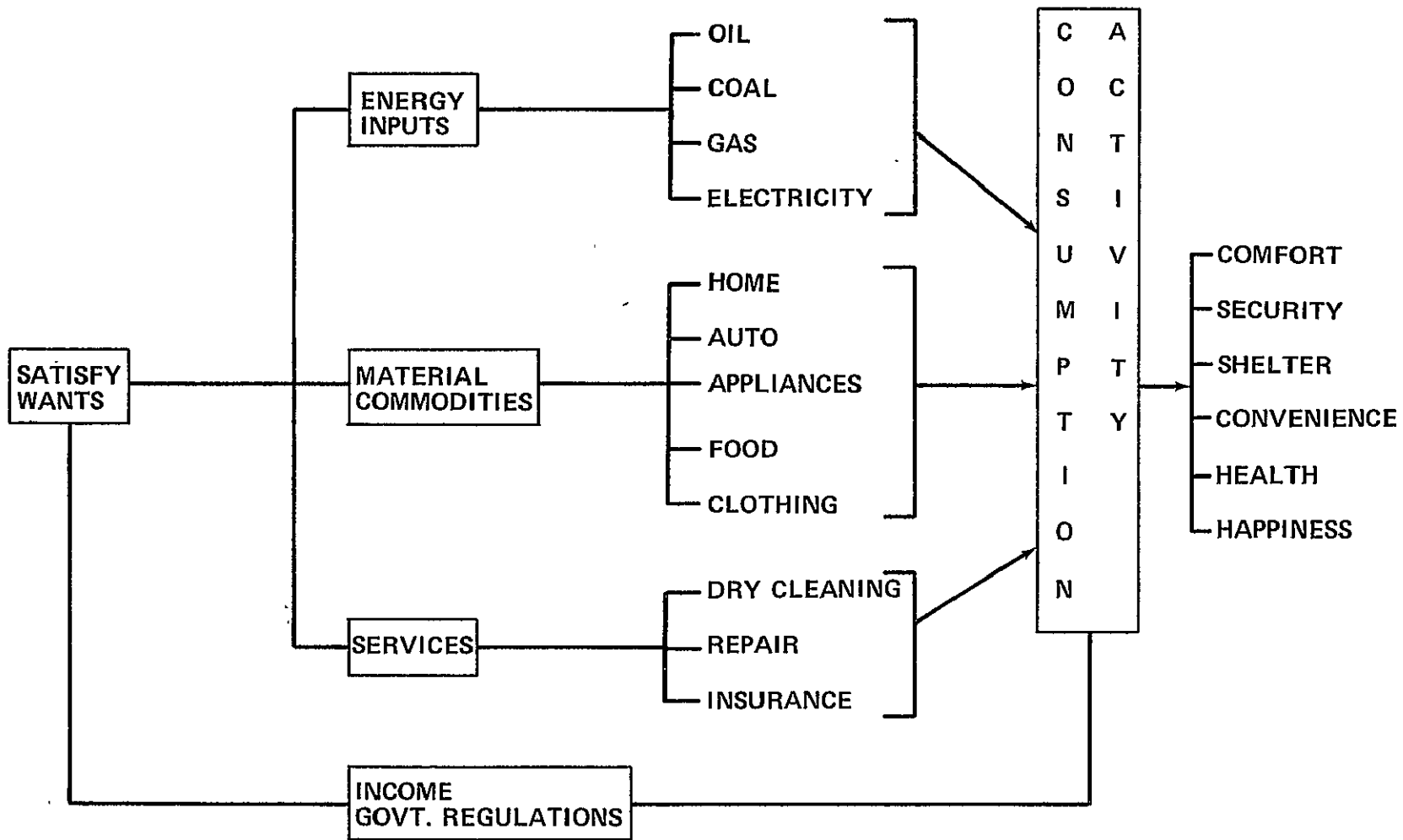


FIGURE 1.2.1-1. NEW APPROACH TO CONSUMPTION (DEMAND)



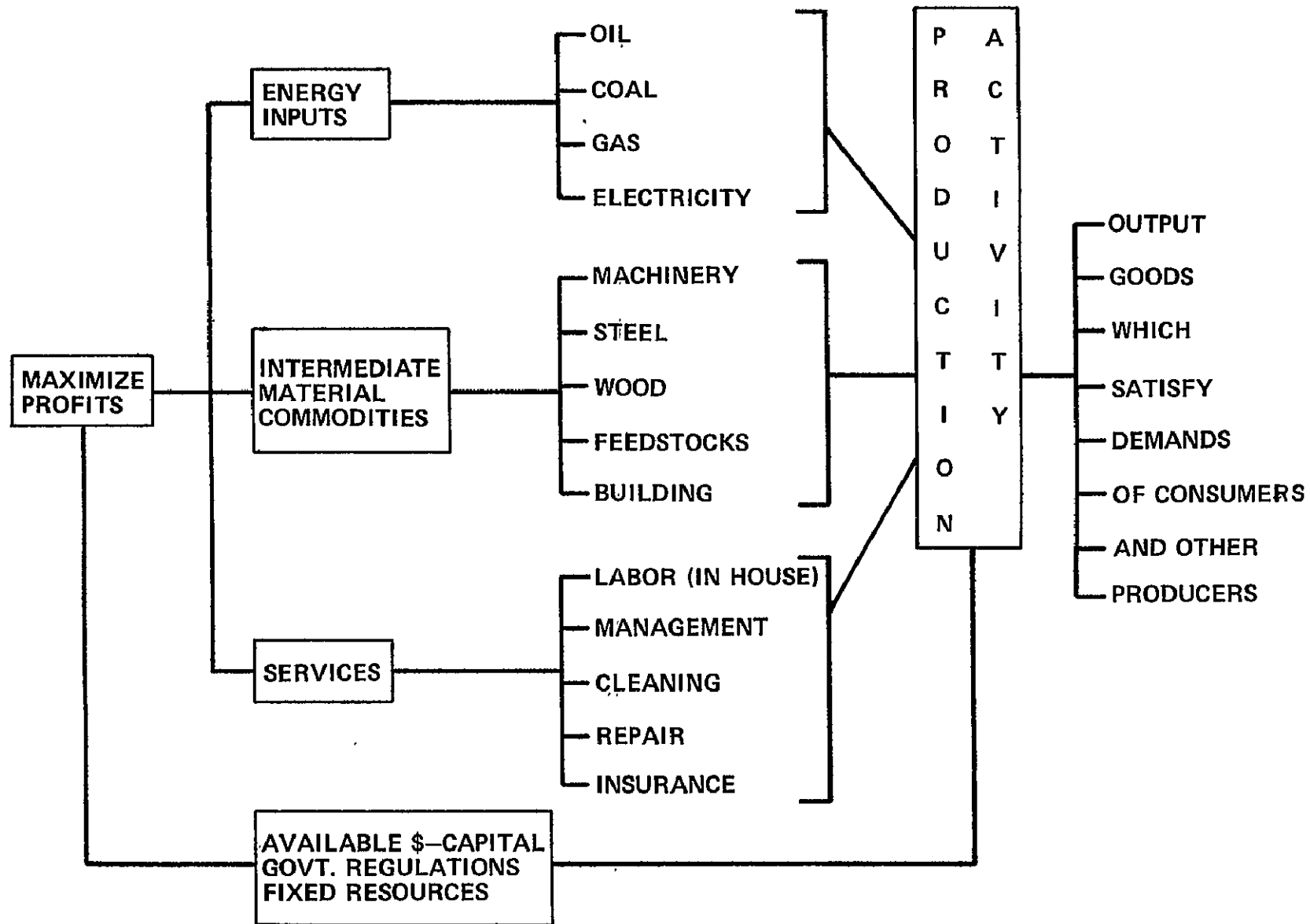


FIGURE 1.2.1-2. PRODUCTION (SUPPLY)

TABLE 1.2.1-1. PRICE ELASTICITY OF GASOLINE

Price of Gasoline (¢/gal.)	Gasoline Demanded (gals./week)		\$ Expended on Gasoline	
	Elastic	Inelastic	Elastic	Inelastic
50¢	20	20	10	10
60¢	10	18	6	10.80

In the elastic case (ratio  $>1$ ), demand was cut by 50% when prices were raised by 20%. The ratio is 2.5. The inelastic case yields a 10% quantity change for a 20% price change. The ratio is .5. Note that when prices go up, expenditure on gasoline generally goes down in the elastic case and up in the inelastic case.

Short run price elasticities for gasoline and other petroleum products have been estimated to be between .2 and .4 [HOUTAKKER-74]. Low price elasticity generally implies that the good is needed, and that there are few or no substitutes. Any market force or policy that raises the price of such a commodity causes its consumers to spend more dollars for slightly smaller amounts. The lower income groups bear a large part of the burden.

Cross price elasticity measures the proportional responsiveness of the quantity of one good to changes in the price of another. An example for goods that are complementary is a decrease in big cars purchased as a result of high gasoline prices. An example for goods that are substitutable is an increase in electric blankets bought as heating oil prices increase.

Available funds elasticity measures the relative responsiveness of the quantity of a good to changes in the amount of funds available. For most goods, assuming prices constant, the amounts used go up as available funds go up. This has important application in the current recession. The available funds of many consumers and producers have been diminishing, both in terms of the amount of dollars (money income) and their purchasing power ("real" income). This generally means that consumption of all products including energy will go down.

Elasticity is also important in measuring the relative responsiveness of quantities of goods supplied to changes in their prices. Two relevant examples are the responses of oil and coal companies to increased prices of their outputs. The short run supply elasticity of petroleum products involves the companies' operations from exploration to the gasoline pump. Implicit also are rigidities in supplies of heavy machinery, plants, foreign crude supplies. This coefficient was assumed approximately 1 [AHC-75,19].

Elasticity, therefore, is an important gauge in measuring the effects of certain policies that alter energy prices and incomes. It, together with the phenomenon of substitution mentioned above, gives much insight into the potential reactions of market forces and government edicts.

### 1.2.2 MARKET STRUCTURE

In the market for energy products (as well as others), the question of the degree of competition has always been raised. The extreme lack of competition occurs when there is a monopoly in a market. If there are no ready substitutes and no entering firms to capture shares of the market, the monopolist will exact the highest price that its customers will bear. If it can discriminate among its customers, a monopolist can extract still greater revenues from them. Electric and gas utilities are regional monopolies within the energy industry. Their monopoly power is held somewhat in check by government regulation. It is well known that utilities discriminate among customers by charging lower rates for larger blocks purchased. There is a current movement to alter this.

Oligopoly is defined as a market with few sellers. Each has a great influence on prices. These firms may produce the same or slightly different goods, may fight by price or advertising, or may collude. A cartel is a form of collusion in which the parties agree to restrict output, charge monopoly prices and divide monopoly profits.

For much of the last 25 years, the world petroleum market has been dominated by 7 big companies. By their current names, they are British Petroleum, Dutch Shell, Exxon, Gulf, Mobil, Socal and Texaco. The American companies dominated the domestic scene. The big 7 dominated the world scene and succeeded in extracting the resources of Mideastern countries for little payment. Due to market dominance and vertical integration (from wellhead to gas pump), there was no real concept of market price. The big oil companies did not initially create a formal company cartel, but worked closely in expanding foreign operations (sharing risk and investments, etc.).

During the last two decades, the oil-rich countries began to accumulate expertise and bargaining power. Using independents as a wedge, they continued to obtain favorable concessions from the oil companies in the form of taxes, royalties and ownership. In 1960, OPEC was formed. In 1970 it had gone from an organization to a cartel. In 1973, it exercised its cartel power against the U. S. and other developed countries which had become increasingly dependent on OPEC oil. It is well known, however, that the ARAMCO cartel represents an international collusion of oil companies and countries.

High world petroleum prices and low Mideast extraction costs have led to an "inefficient" allocation of resources and an "excess" flow of wealth to the Mideast. A breakdown of industry data for January 1971 and January, 1974 is given in Table D.2.1-12 in Appendix D.

Horizontal integration of oil companies into other sources such as coal and uranium appears likely to further limit competition in the energy industry. Coal and uranium present competition to oil and gas and have the potential for lowering their prices. They generally, however, come to the consumer in the form of electricity.

Monopolies and oligopolies in the energy industry usually continue to exist at various stages of production because of the large amounts of capital required for entry. These will become even greater as less attractive sites are exploited. The hopes for increased competition, in the sense of many firms striving to be efficient and to charge lower prices than the others, are dim. The retort is that the economies of scale which accrue to bigness are beneficial to customers. That debate is beyond the scope of this report.

### 1.2.3 AGGREGATE FLOWS

The macroeconomic aspects of energy economics are schematically represented by the Economic Actions-Impacts Flow in Figure 1.2.3-1. Because of the interdependence of the sectors, any action or policy taken in one arena has important impacts in many of the others. The Residential/Commercial sector provides labor, other services and money which itself and other sectors use. Industry uses the goods and services of the other sectors to produce and sell its outputs. It receives money for these while it pays itself and other sectors for what it needs from them. The Energy Industry uses resources and other products and services to provide fuels for direct use and electricity. It receives payments for this activity while paying other sectors for their resources, goods and services. Transportation does basically the same in the provision of transportation services. The Government performs services with monies collected as taxes. It also purchases goods and services from the private sector. Implicit in the flow, for example, are the markets for specific goods and services, markets for specific types of labor and markets for money. From them come prices, wage rates and interest rates. These in turn are projected to the micro units for everyday decisions. An example in the energy industry is the current high interest rate structure which, with inflation, impedes large investments by utilities and oil companies.

The historic relationship of energy consumption to GNP has been strongly positive. Much of the debate over the "BTU theory of value" is related to the question of whether or not GNP should continue to grow, and if so, can energy consumption remain constant? Efforts to affect flows to and from the energy industry have significant implications on the distribution of wealth even if the total pie remains constant. As mentioned above, real income erosion has important regressive effects in itself. The controversy between President Ford and Congress is strongly tied to this issue.

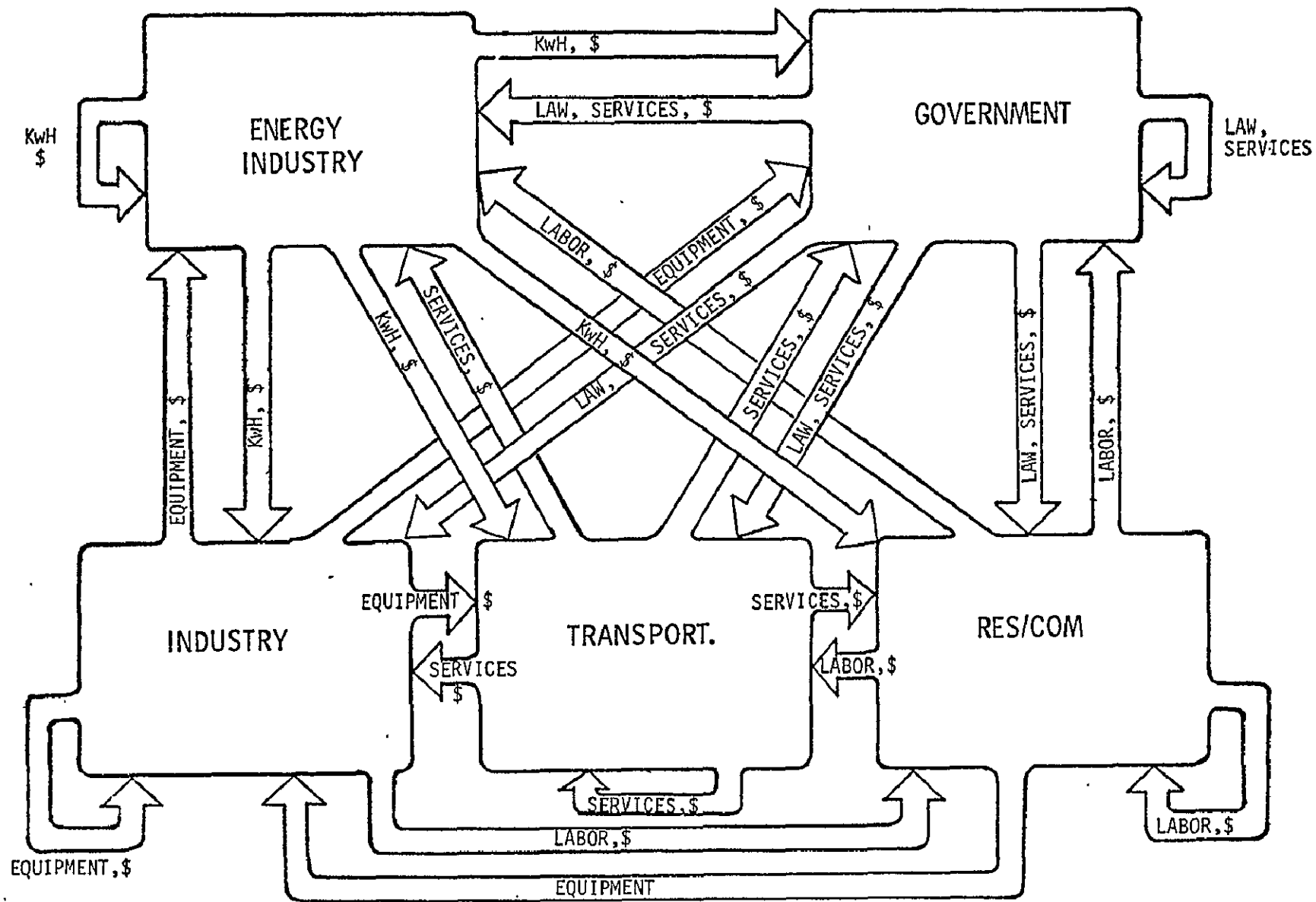


FIGURE 1.2.3-1 ECONOMIC ACTIONS-IMPACT FLOW

Much information on the operation of the macro-political economy is gotten from econometric models and input-output analysis. This report shall defer to Project Independence [PI-74] in the former area, but will use the latter to draw some conclusions about conservation actions.

### 1.3 THE ROLE OF GOVERNMENT

Various levels of government have been closely tied to the energy sector for many years. Several of the federal agencies involved with energy are mentioned in Appendix N. Hosts of state and local governments and their agencies have jurisdiction over land use, public utility pricing, etc. They are too numerous to mention here by pure quantity and by diversity. It is not clear at this point how a centralized energy plan would reconcile itself with the plethora of diverse local regulations

An important fact has been the lobbying power of the giant energy concerns. Much of the governmental policy has been swayed by those who emphasized the importance of the energy supplies to an industrially growing nation.

As will be discussed below, the President, Congress and the agencies previously established (FEA, ERDA, FPC, etc.) are busy with proposals to "solve" the energy problem. These range from researching the electric car, through deregulation of oil and gas prices and imposed energy efficiency standards, to forestalling expansion of nuclear power. A list of some of these measures is given in Appendix N. The public officials are anxious to develop a consistent, cohesive energy policy, but are concerned over the potential impacts. It is the hope of this study to provide insights into these areas.

As a final statement on energy industry regulation, it should be noted that the three major factors that determine profits are total revenue from sales, total costs of production (fixed capital investments plus variable operating costs such as resource costs, wages, interest, etc.) and constraints on the operation of the firms (EPA, SEC, etc.). All of the regulatory actions affect the revenue and costs of the energy firms. The recently high profits of the oil companies and the decrease in internal financing of public utilities are two main areas of concern for policymakers.

### 1.4 CONSERVATION ACTION-IMPACT FLOW

As seen in Figure 1.2.3-1, the combination of market activity and government regulation presents a very complex system. Conservation, as described in the next chapter, presents a broad characterization of actions and impacts which are the main body of this report. Its role in the overall action-impact flow is examined as substitutes and complements for the status quo are proposed. The group shall look at broad direct actions of the energy subsystems, subactions that comprise these broad actions, other important actions not necessarily belonging to the broad actions and indirect actions which are called impacts.

## CHAPTER 2. CONSERVATION: TOWARD FIRMER GROUND

The particular form of conservation to be assessed in ECASTAR is that which is compatible with the existing economic and political constraints in the U. S. today. The ECASTAR form of conservation relies heavily on the market place and well understood technology to cushion the social shocks of the energy problem. This is by no means the most powerful form conservation actions could take. ECASTAR deals principally with evolutionary changes in energy use to achieve conservation. The imposition of economic, political, and technical constraints based on actual conditions allows application of a systematic, quantitative, assessment method under widely accepted performance criteria.

### 2.1 CONSERVATION HISTORY AND GOALS

The purpose of this chapter is to set the stage for an assessment of energy conservation. The Introduction to ECASTAR has provided a cross section of current feelings about conservation. In this chapter conservation will be placed as a component of a wide ranging multifaceted energy policy. A proper definition or characterization of energy conservation requires a careful review of its history of successes and failures, its current priority with energy users, the peculiarly fleeting aspects of the opportunities for and justifications of conservation, and the state-of-the-art limits on energy savings.

There are two important facts in the history of economic-technical conservation. The first is that in an era of stable or declining real prices for energy ('50's, '60's) significant conservation gains have been achieved by many industries and many energy or fuel producers. The second is that while energy producers and industry were practicing efficiency, consumer energy use was being pushed up by rising sales of energy intensive goods and services. The time profile for the recent history of conservation contains three major periods. The first is the period of stable or declining real prices of energy brought about by government regulations, expanding supplies and economies of scale or efficiency. This period ended in the late '60's. The second period is one of gradually increasing energy prices due to general cost increases, government regulations on pollution and health, citizen involvement in environmental decisions, and some weakening of the supply picture. The third period is identified with the 1973 embargo and its aftermath. It is characterized by escalation of energy prices, insecurity of sources, general recession, and a broad-based concern for a long range energy supply and consumption policy.



Contrast the achievements and failures of unsupervised energy consumption in the two examples:

The chemical industry has reduced its energy consumption per pound of product by 50% from 1954 to 1971,

The electrical utility industry has been forced to meet an ever increasing peak load problem which strains their capital resources and forces the use of inefficient peaking plants to meet consumer demand.

This report documents many other cases of improvements in energy utilization and of decreases in energy effectiveness.

A view as to what constitutes conservation is dependent upon the history of energy utilization effectiveness and upon the conditions of price and availability existing now and projected into the future. A large group of conservation actions results from a history of wasteful and inefficient past practices. Even the definition of waste is controlled by the urgency of a need for fuel. To some, our lifestyle is redolent with waste. To others waste is leaving coal in a mine to prop up the roof. A third view is that it is a waste to use one's own resources if someone else's can be utilized as easily. More will be said of this three-way view of conservation in the section to follow on modes of conservation actions. It is important to realize that all judgements about conservation are dependent on the peculiar features of the present energy situation and the particular decisions in the past which shaped our supply and consumption patterns.

Much is presently being said about setting conservation goals. In particular, many efforts are being made to encourage conservation actions without mandating them. This report addresses the question of attainable goals in considerable detail. A characteristic of current conservation thinking is that most proposed changes involve isolated components or sub-systems of the larger energy supply and use systems. Little or no attention is given to assessing sweeping redesign of whole energy utilization systems and the integration of many proposed sub-systems into larger systems. This study looks at significant system redesign in the cross-cut examinations of (1) a policy of electrification of the nation's energy use and of (2) a policy of diversifying the nation's energy supply as widely as technology and economies allow.

Conservation opportunities and needs arise out of the context of present and future societal operations. The choice of an implementation method of a conservation goal is an altogether different study from that of identifying targets of opportunity for correctable waste. In particular, all conservation actions must be assessed from the point of application to the chain of raw materials to intermediate products, and through to consumer activities. There is good reason to believe that significantly more can be achieved in overall impact by attacking the end uses of products and energy instead of attacking just the obvious

large consumers of energy. This is a point of crucial importance in formulating policy and illustrates the combined power of an engineering and economic systems analysis.

Some examples of conservation goals which industry and government see as attainable are:

A 20% industry wide reduction in energy per unit of output by 1980 relative to 1972.

A 40% improvement in automobile gasoline consumption by 1980 relative to 1974.

A 40% reduction in energy consumption of new commercial buildings.

A 20% improvement in the conversion of fuels to electricity (40% raised to 50% conversion efficiency) by 1977.

There is considerable tension between government and industry over establishing even voluntary goals, much less mandatory ones. There is evidence of resistance to setting goals and providing data to evaluate attainments. The conflict between long-term benefits and actions which complicate a product or weaken market potential is going to exist for some time. Many proposed mandated goals are double the industrial goals. Consumer action goals are also being considered, both voluntary and mandatory.

## 2.2 CONSERVATION MODES

Energy conservation can be divided into categories that include all actions which affect the form or amount of energy consumed -- reduced energy consumption, increased efficiency of energy utilization and substitution of one or more forms of energy for another which is in shorter supply or in some sense thought to be of more value.

Reduced consumption affects the demand side of the energy equation. It can be effected either voluntarily or by mandate. In either case it may lead to changes in life style if continued over an extended period, although this is not necessarily the case. Reduced consumption may be instituted, even if the supply is sufficient, in order to extend its lifetime. Rationing and individual efforts to reduce expenditures for energy are examples. In some cases, immediate shortages in energy supplies might force curtailment of consumption, as happened during the oil embargo.

Of all of the modes of conservation and all of their separate means for implementation, conservation by reduction of final demand will have the strongest effect on the overall economy. Altering the size of final markets alters every step in the economic chain from raw materials to intermediates to final products. Actions in this area must be carefully assessed for direct and indirect effects on jobs and earnings. Care must be exercised to allow actions to produce their full effect before sudden new steps are taken.

Increased efficiency of energy utilization employs technology to increase the ratio of useful output to energy input. This may be viewed as obtaining more output for the same input, or the same output for less input. Another view sees increased efficiency as matching the quality of the energy input to the task, as in the case of using low quality waste heat for space heating or hot water heating. In the past, systems have been designed with little attention paid to efficiency because of the abundant supply of cheap energy. Thus it can be expected that in the future considerable savings may be realized by redesigning systems such that optimum efficiency is a criterion of design. Additional savings should accrue from matching of quality of energy to the use and utilization of previously discarded waste low grade energy.

The third means of energy conservation involves substitution of energy forms such as coal or nuclear for oil or gas. In a more general sense this category of energy conservation can be realized by resource substitution at any point in the production or utilization sequence. Some examples of substitutions that might result in energy savings are:

Labor for machinery

Recycleable material for non-recycleable material

Non-energy intensive material for energy intensive material

Renewable energy source for a non-renewable one (solar for oil)

The industrial era is characterized by a transition from using renewable energy sources to the use of non-renewable stored sources. A reversal of this trend holds promise for large savings of non-renewable energy sources.

A point which should be emphasized is that conservation is motivated by some or all of the following:

A conservation ethic or moral commitment to conservation

Economic necessity

Legislative decree or other government action

A further discussion of these motivating factors, as applied to the modes of conservation, will be found in the succeeding chapters.

### 2.3 CONSERVATION ACCOUNTING - CRITERIA

Acceptable conservation actions are those which meet certain criteria. Rather than these being absolute criteria, they are relative to conditions at the time, past history and projections of future needs. The view of the present and future is dependent on the recognition of the constraints on possible actions and on a body of feeling called conventional wisdom. One of the goals of assessment is to examine conventional wisdom and put a systematic structure into arguments pro and con. A component of an assessment is the application of the constraints to those actions deemed attractive with a view to changing the focus of the constraints if there are benefits to doing so. Constraints and conventional wisdoms are described in other sections of this chapter.

Some major criteria are listed. The result of actions must satisfy these if the actions are to be classed as conservation.

The modes of conservation discussed in Section 2.2 included curtailment of demand, substitution, and increased efficiency. In today's condition with uncertainties about reserves and technology some of the criteria are:

Imported oil is "more valuable" than domestic.

Natural gas is "more valuable" than domestic oil.

Oil is "more valuable" than coal for stationary uses.

Oil has no substitute for transportation uses.

Low sulfur fuels have an undetermined premium over high sulfur fuels.

Coal is "less valuable" than almost any other source.

Most other criteria depend on subjective ranking of political and social goals. These criteria apply simply to substitutions of fuels. The idea is that conservation actions guard the more valuable fuel form. It is already apparent in this short list that present conditions and intentions are not rigorously compatible with these criteria. There is national conflict of opinion over the level of importation of oil. Natural gas is treated differently depending on whether it is compared to domestic or imported fuels and whether it is controlled by federal regulation. The obvious great value of oil is tied to the large transportation demand. However, the smooth functioning of a refinery dictates that products other than transportation fuels must be produced. This precludes reserving even this one fuel to its unique use. The same contradiction exists in the uses of natural gas.

### Net Energy Reduction Criterion

In the area of curtailing demand for energy or products in the hope of reducing energy consumption, any criterion must carefully specify the accounting boundary in determining if net reduction in energy use has been achieved. The goal of achieving a net benefit by some action directed at reducing consumption is immediately suspect in that the economic repercussions may be larger than can be controlled. There are many ways of defeating a criterion requiring a net energy use reduction. One way is if an activity replaces that curtailed which is more energy intensive or contributes more demand in another area leading to a net increase in energy consumption. As an example suppose demand for clothing is reduced by making clothes last longer. On the surface this saves energy in the energy intensive natural or synthetic fibers. It also saves some money for the consumer. Almost everything the consumer might do with his savings leads to more energy consumption per dollar and generates fewer jobs per dollar. Just paying taxes is 15% more energy consuming than buying men's clothes. [Hammon-75]

It is not clear that a criterion requiring an action to generate a net energy reduction can ever be checked. Without further specification of actions initiated after the given action there is no way of guaranteeing that the net effect is known. This raises the spector that the only way of reducing energy usage by changing demand is to guarantee total demand is reduced, and that the changes of each activity are weighted by their respective energy intensiveness.

A net energy criterion can be developed to measure the value of efficiency changes. It is still essential to define a boundary within which all derivative effects are accounted for. In particular, the simplest type of action leaves the output of a process unchanged and makes only modifications or minor substitutions to the process itself. In this case there is little chance that the total energy accounting on all the imbedded energy will differ much between the two processes. Therefore a comparison of easily measured purchased energy will determine if net savings have been achieved. A related parameter is the energy payback period of an action. Many advanced technologies and system redesigns will take some time to return the energy of manufacture and installation. No uniform criteria exists on payback of energy.

Strict net energy accounting can be applied to simple substitutions of materials, components, or subsystem with a view to increasing efficiency. There are no simple criteria to evaluate the full system substitution or strategy substitutions. In assessing a major systems change, for example a portable fuel alternative to petroleum, the impacts would be so wide-ranging that conservation could not carry enough weight to be decisive. Only narrowly defined actions can be successfully assessed with respect to a few sharp criteria. The larger actions will require impacts and modeling of the whole picture of economic and social changes for assessment.

One of the principle uses of criteria is in evaluating actions. The alternatives must be closely matched as to level of action, boundaries for derivative effects, and factors to be held constant. Otherwise it is not reasonable to compare them to each other or to some objective criterion. There are not very many instances of true alternatives among the actions assessed in this report. Thus our criteria sets are specialized by sector and other variables. Not many of the criteria are general. The obvious one of net energetics is, as pointed out above, either difficult to define or of relatively small influence.

The subject of performance criteria deserves careful research. There are many fruitful problems which when elaborated would contribute to national understanding and national policy on energy and energy conservation. Further discussion of criteria is found in Chapter 3 and Appendix C.

### Economic Criteria

In the class of economic criteria two simple ones are to minimize initial cost or minimize life cycle costs. The conservation oriented criterion is life cycle costs. For those activities in which fuel costs are a large share of operational costs, it probably follows that reducing operating costs reduces fuel consumption. The same caution that applied to net energetics applies here. Careful definition of the boundaries of the system and the level of inputs and outputs is needed in order to make comparisons. With respect to first costs it is important to define the criteria on rate of recovery of conservation oriented investment. The attitude today is that conservation investments must recover their costs faster than other types of investment to be attractive. Similar attitudes exist toward environmental protection steps. The attitude is that they should be expensed very rapidly or otherwise subsidized. A controversy exists about whether attractive investments in conservation will be made at all if there is no restriction on passing through energy costs. Criteria which measure some "good", like net energetics or minimum life cycle costs, do not of themselves dictate actions.

### Technical Criteria

The role of technical criteria, such as those in existence or some which might be defined to reflect peculiarities such as form value of fuels or declining reserves, is not clear. The realities of the present situation are that little attention is paid to technical recommendations. For example, much more attention is directed at nuclear safety uncertainties than to the impact of low utilization of nuclear energy on coal use

and related pollutants. Similarly, many attempts are being made to raise taxes on all phases of utility operation and to increase government and public influence in their expansion planning regardless of the impact on the consumers energy bill. Little attention is given by decision makers to other technical questions such as maintaining an orderly atmosphere for planning and to preventing supply oscillations by properly accounting for lead times.

In summary, the important criteria are those actually used. Chapter 3 addresses the problem of defining and validating new technology-based criteria. More general areas for new criteria arise in the combination of impact analysis with the systems approach. In general, the assessment must show tolerable impacts. It is not possible to decide tolerable impacts in the abstract. These will emerge in situations where assessment will lead directly to decision, not just to a study result.

## 2.4 A METHOD TO OVERCOME OBSTACLES

Energy conservation is one of many highly prominent topics today. It has certain features which complicate the organization of discussion, problem formulation, analysis, and decision making. The features include:

Direct personal impact on everyone

Impact on life style, income, security, aspirations

Connections to the "they" in life: big government, big business, big politics

Involvement of known and speculative science and technology

Large scale involvement of environmental, safety and health issues

Elements of the infinite: whole nation, whole world, all time

Appeal to moral and ethical standards

An element of crisis

The transient nature of opportunities to correct the system.

These features produce a reaction that can be described as conventional wisdom. This body of partitioned thinking, plus the status quo with respect to existing laws, regulations, investments, and job spectra, constitutes the source of a priori constraints on planning for conservation. We argue here that it is not possible to construct a broad balanced view to aid planning by compounding the narrow views embodied in conventional wisdom. Also, it is impossible to plan effectively if the a priori constraints are not identified at the outset.

A method must be found and applied which transcends the prejudgment characteristic of conventional wisdom, identifies alternate courses of action compatible with a priori constraints, evaluates their actions, and assesses their impacts in terms of a posteriori constraints and criteria. An important element of an evaluation leading to concrete decisions (not just to a "study conclusion") is that the final criteria must spell out tolerable limits to compromises in the solution. A characteristic of the conventional wisdom is that it is intolerant of compromise.

To illustrate some of the conventional wisdoms, some points of view and tentative counters to them are listed.

Conservation is good. What if it causes unemployment, decrease in productivity and wages, or results in more energy intensive activities?

There is a semi-infinite source of economic, safe energy accessible except for some solvable technical problems. Technology has been wrong or failed to deliver with increasing frequency. The scale of associated problems and impacts is growing faster than the scale of the technology.

Conservation measures can be instituted individually. This ignores the facts of interfuel competition and the ripple effect of changes throughout the economy.

Conservation measures should be mandated. Even gradually initiated mandatory actions create dislocations which seem to cry for more action but must be accepted for some time to assess their size and impact.

Conservation can alleviate the energy crisis without decreasing national prosperity. The embargo and changing car buyer attitudes clearly indicate that reduced demand either voluntarily or involuntarily will slow growth and impede recovery.

Conservation and environmental costs should be internalized. Major industries, utilities, and consumers actively resist accepting either type of cost. Decision makers fear the reaction of constituents should these costs be assessed.

Conservation can be achieved by gradual alteration of present energy use patterns. There are much greater potentials in full redesign of the energy system by beginning transitions now before supplies restrict options. No mechanism exists in government for accomplishing a system redesign of any major system. No method exists for assessing large scale social engineering before the fact.



The elements of a method for formulating a problem, such as that of finding a workable approach to energy conservation, are directed by establishing a starting point and a set of rules. The starting point is the objective plus a set of requirements. The rules are constraints (a priori and a posteriori) and criteria. The operation of the method is to assign weights to alternative implementations of the requirements and to document the consequences of combining the alternatives according to the different weights.

The method must combat the destructive tendencies toward comparing actions or impacts of different order, failure to agree on a weighting system, failure to search for any alternative, failure to examine consequences and impacts in like detail before comparing alternatives, and failure to search out negative impacts with the same diligence of imagination applied to positive impacts.

## CHAPTER 3. ECASTAR SYSTEMS APPROACH

The methodology of ECASTAR is presented and a discussion of the application of technology to energy conservation is given. The ECASTAR methodology constitutes an overview and blueprint for the analysis of energy conservation actions.

### 3.1 THE METHOD

#### 3.1.1 THE SYSTEMS APPROACH

The methodology for the ECASTAR study was based on a systems approach to develop, display and characterize the problem of energy conservation. A number of tools were used in conjunction with the systems approach employed. The primary tools were -- INPUT/OUTPUT ECONOMIC ANALYSIS, NET ECONOMICS and NET ENERGETICS. These tools are discussed in 3.3 and 3.4. This section outlines the systems approach.

Figure 3.1.1-1 indicates a display of the systems approach process. The process can be divided into four phases.

- Phase I - The definition of the objective and constraints and criteria;
- Phase II - The establishment of the requirements necessary to meet the objective;
- Phase III - The determination of possible alternatives to the requirements;
- Phase IV - The tradeoff (analysis/synthesis) where tools such as decision theory, input/output and other assessment techniques are employed to select a final strategy, plan or device to satisfy the objective.

This approach permits each phase to be a separate sub-system study, and this is illustrated in Figure 3.1.1-2. The figure shows the requirement of a systems approach display as the objective of a sub-systems approach display. This resolution can be continued further resulting in a sub sub-system approach display for the requirement of the sub-system approach and so on until each piece of the problem becomes tractable. Each requirement of the systems approach study can be resolved as illustrated in Figure 3.1.1-2. Analysis of each of the elements displayed through this resolution is carried out at the sub and sub sub-system levels. The results of the sub sub-systems approach studies are combined at the next higher level in an integration process. This process is repeated until the original systems approach level is reached and the systems approach process continues to a conclusion.

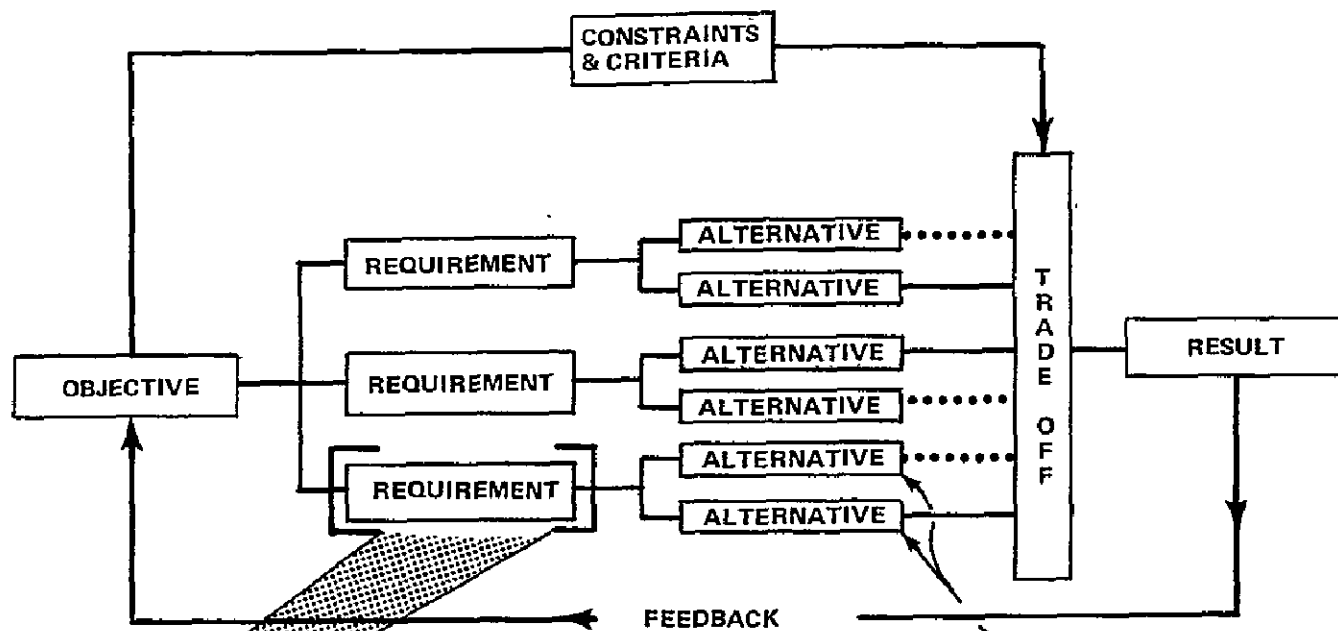


FIGURE 3.1.1-1. SYSTEMS APPROACH DISPLAY

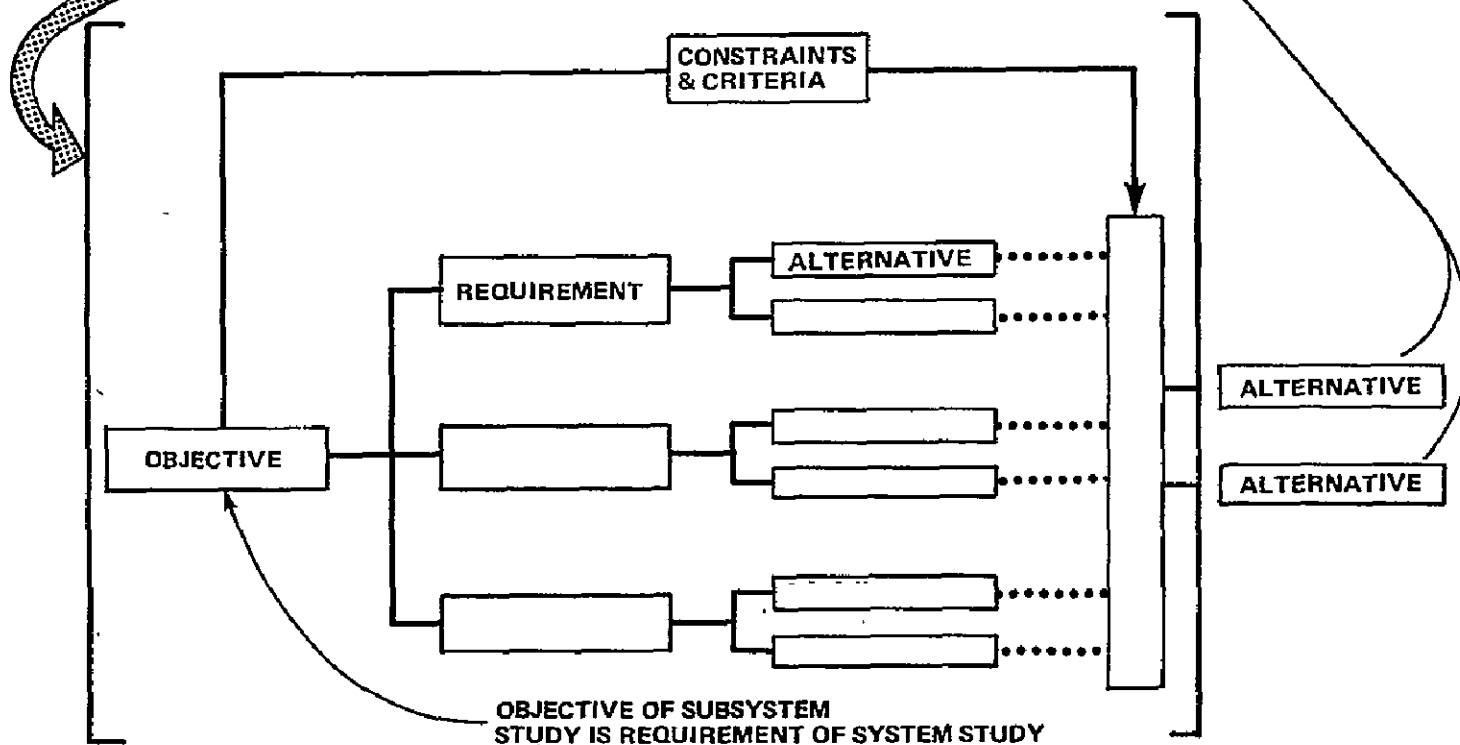


FIGURE 3.1.1-2. SUBSYSTEM APPROACH DISPLAY FOR SYSTEMS APPROACH

The words or terms objective, requirement, alternative, constraint, criterion and trade-off as used herein are characterized as follows:

- objective -- the function that the system or strategy must perform or accomplish
- requirement -- a partial need, stated in generic form, to satisfy the objectives;
- alternative -- one of many ways to satisfy a requirement;
- constraint -- limitation within the framework of the study;
- criterion -- desired feature of a system or strategy;
- trade-off -- applying selection criteria and constraints to choose the combination of alternatives to meet the objective. The trade-off process often requires the application of many other techniques such as technology assessment.

Constraints and criteria deserve discussion since these terms constitute the category of statements that govern trade-off. The identification of constraints and criteria is a problem to the systems approach practitioner. These terms are discussed in the next section.

### 3.1.2 CONSTRAINTS AND CRITERIA

Constraints and criteria were established by the group. Some were established a priori, while many others were identified during the course of the study. These terms are discussed as follows:

#### Constraints

In a very general way constraints are existing limitations of a study. They are part of the status quo. Something becomes a constraint on a proposal when it interferes with that proposal being acted upon.

It is quite reasonable and perhaps instructive to classify constraints in accordance with their degree of inviolability.

#### Logical Constraints

The first class of constraints might best be referred to as logical. Embodied in every thought, action, decision or judgment is a set of pre-judgmental presuppositions which determine in a strictly logical sense the validity and consistency of a decision. One can propose inconsistent actions, but one cannot expect them to reach fruition.

### Empirical Constraints

Empirical constraints are determined by the limits of theoretical or scientific possibility. There are a set of natural laws which limit in a very definitive manner the kinds of ways in which a problem can be approached. The kinds of proposals which empirical constraints would be expected to check are epitomized by suggestions of perpetual motion machines and devices which would show net energy gains. A characteristic shared by logical and empirical constraints is their virtual immutability. Practically speaking, they delineate absolutely a boundary to possible action; they tell what cannot be done under any circumstances.

### Technological Constraints

Perhaps no empirical impediments exist which would seemingly preclude the possibility of an action, but the action's impossibility may still be a fact simply because of the lack of technological sophistication.

It is true that the limits of technological possibility change over time. A breakthrough today makes yesterday's impossibility a reality. Technological constraints are not absolutely fixed; they depend on specific time frames. It is clear that the temporal length of specific technological constraints can be changed depending upon several factors including the degree of interest shown.

### Institutionalized Constraints

Institutionalized constraints include social, political, economic and legal aspects of the current situation in the United States and the world. Expectations and aspirations, styles of life and income distributions, voting habits, political apathy, corporate policy, governmental policy at all levels, and preparations for the Nation's bicentennial all contribute to the overall background of constraints. By their very nature, institutionalized constraints change. To effect conservation, some institutional constraints must change. Not so obvious is what needs changing.

### Criteria

Unlike constraints, criteria reflect desired rather than existing features of a system. And in some important respects relevant criteria can be identified before engaging in an analysis of the problem. Criteria are not strictly a priori; several may emerge once study of the problem is commenced. A statement of criteria indicates a desired or sought condition as opposed to constraints which indicate an existing or anticipated limiting condition.

One of the important classes of criteria and constraints which needs to be considered in any evaluation of an action or society as a whole includes both human and social factors. Perhaps the best reasons for dealing with this area are moralistic and humanitarian. There is a growing public concern and level of awareness for the development of new technologies. Some of this concern has been negative. Some concerns have effectively impeded if not halted progress in some areas. Technically sound programs failed to take account of human attitudes, fears and interests. Thus, in the past decade a number of programs which had excellent potential for improving the current energy situation have been set back. Extravagant impediments were encountered in the Alaskan pipeline program, and in virtually every nuclear generating project increasingly stricter licensing difficulties continue to develop. An abundance of these problems might have been avoided or at least anticipated had human factors, that is, attitudes toward the environment and concern for public safety, been taken into account. Of course, attitudes change or develop in response to a given situation and it is not always possible to anticipate human factors. Thus, the economist, technologist and sociologist face a dilemma when looking to the future, even if a systems viewpoint is adopted.

#### Constraints and Criteria in Trade-off

Unquestionably, there can be significant clashes between criteria and constraints. For example, the energy costs of recycling metals of almost every kind is far less than that of mining, transporting, and refining metal bearing ores. An obvious conservation action, therefore, is to improve recovery methods and increase the reprocessing of discarded and unused metals. But this action encounters a constraint. The Interstate Commerce Commission (ICC) which regulates the freight prices charged by railroads provides for a price structure which directly corresponds to the market value of a good being transported. The price established for recycled metals is accordingly higher than it is for ores, so much so in fact that economic incentives to the refinery for utilizing recycled materials are relatively low. Even the most general criteria indicate the desirability of decreasing the overall amount of energy used, but ICC policy interferes with these criteria. A new action, therefore, seems indicated: a change in ICC policy. The clash occurs between the constraint (i.e., present policy) and the criteria (i.e., to reduce energy consumption at the refinery). In this hypothetical situation, the recognition of the constraints as an impediment comes only after the action has been proposed. Engaging instances of this type arising at every level of action make the context of discovery for constraint-criteria clashes very interesting.

## 3.2 APPLYING THE METHOD

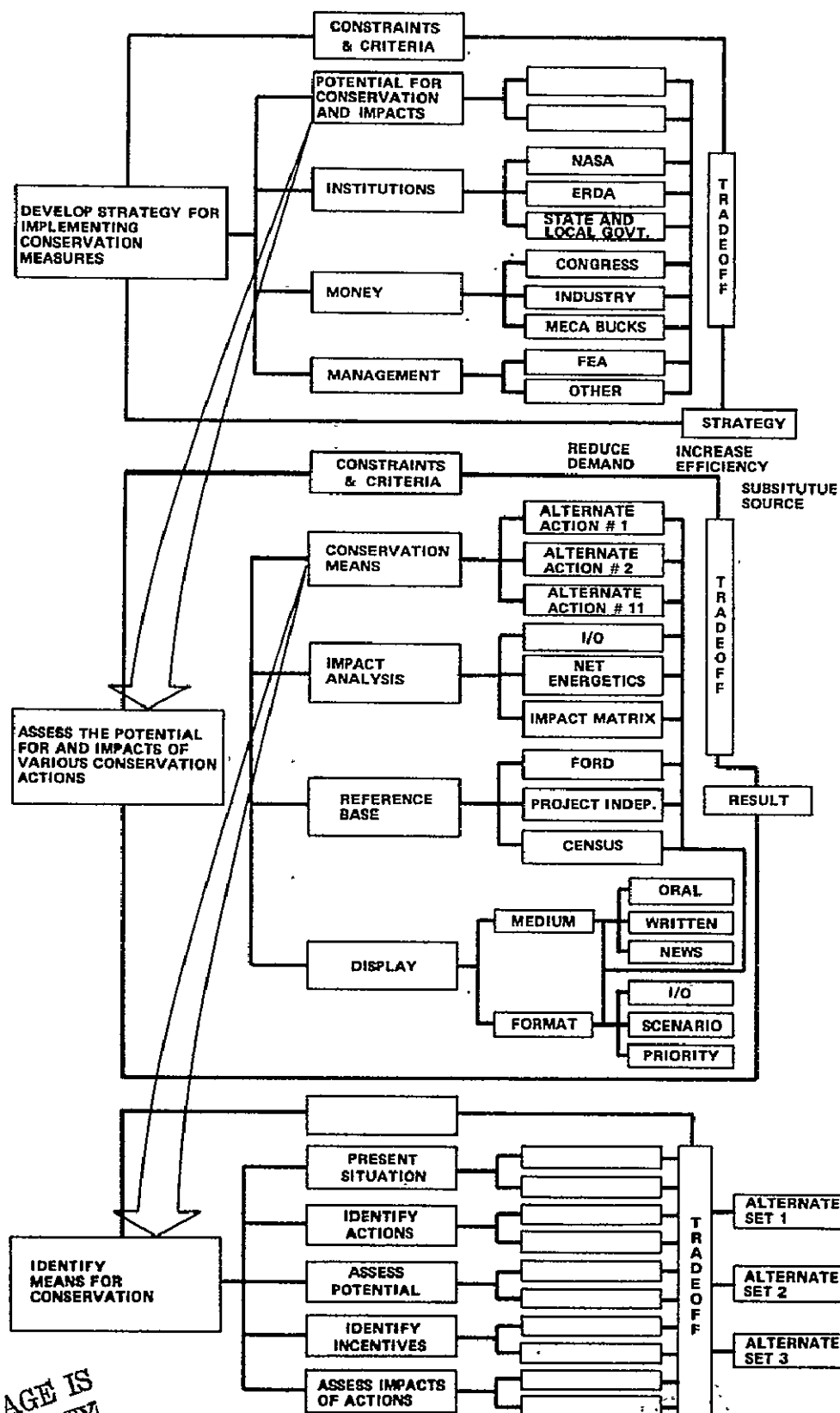
### 3.2.1 SYSTEMS APPROACH DISPLAY

The ECASTAR group applied the systems approach to the topic of energy conservation. The group constituted an information system that collected data, processed the data using the systems approach and displayed the results in this report. The group collected data through seminars, reports and telephone calls. There were interactions with at least 180 individuals, corporations, institutes, universities, government groups and others during the 11 week period. The seminars are summarized in Appendix M.

The display of the energy conservation problem as viewed by the group is seen in Figure 3.2.1-1. This figure illustrates that energy conservation can be viewed at different hierarchal levels. The highest level is at the national policy level. If one assumes that the nation has adopted a policy of energy conservation then there must be a strategy for implementing conservation measures. Figure 3.2.1-1 shows this concept in terms of a systems approach display. Several requirements are shown as necessary to develop a strategy. Some of these requirements are an assessment of the potential for energy conservation and the impacts of the conservation actions, institutions to develop and implement conservation actions, money to finance and sustain conservation actions and a management group to manage or administer the conservation strategy. Other requirements are also necessary but unidentified. Each of these requirements has a number of alternatives. Those alternatives were not selected by the ECASTAR group. Instead, ECASTAR studies the first requirement for the strategy. This requirement has been the sub-system study objective, to assess the potential for and impacts of various energy conservation actions. This objective and associated requirements and sub sub-system studies were the focal point of the ECASTAR study. Figure 3.2.1-1 shows the systems approach display and indicates in abbreviated form the objectives, requirements and alternatives thought necessary to develop a systematic understanding of energy conservation. The blueprint for the study is embodied in Figure 3.2.1-1 and ECASTAR follows the blueprint. ECASTAR does not pretend to be a complete study of energy conservation but does try to show a way to view energy conservation.

### 3.2.2 ECASTAR TEAM

The ECASTAR team was composed of the twenty-one faculty cited earlier. They organized themselves in task groups and elected task group leaders and a project leader three times during the course of the 11 weeks so that there were three sets of leaders. Each set served for approximately 1/3 of the 11 weeks in successive terms. Figure 3.2.2-1 shows the task group



ORIGINAL PAGE IS  
OF POOR QUALITY

FIGURE 3.2.1-1

# SYSTEMS DIAGRAM FOR ECASTAR STUDY



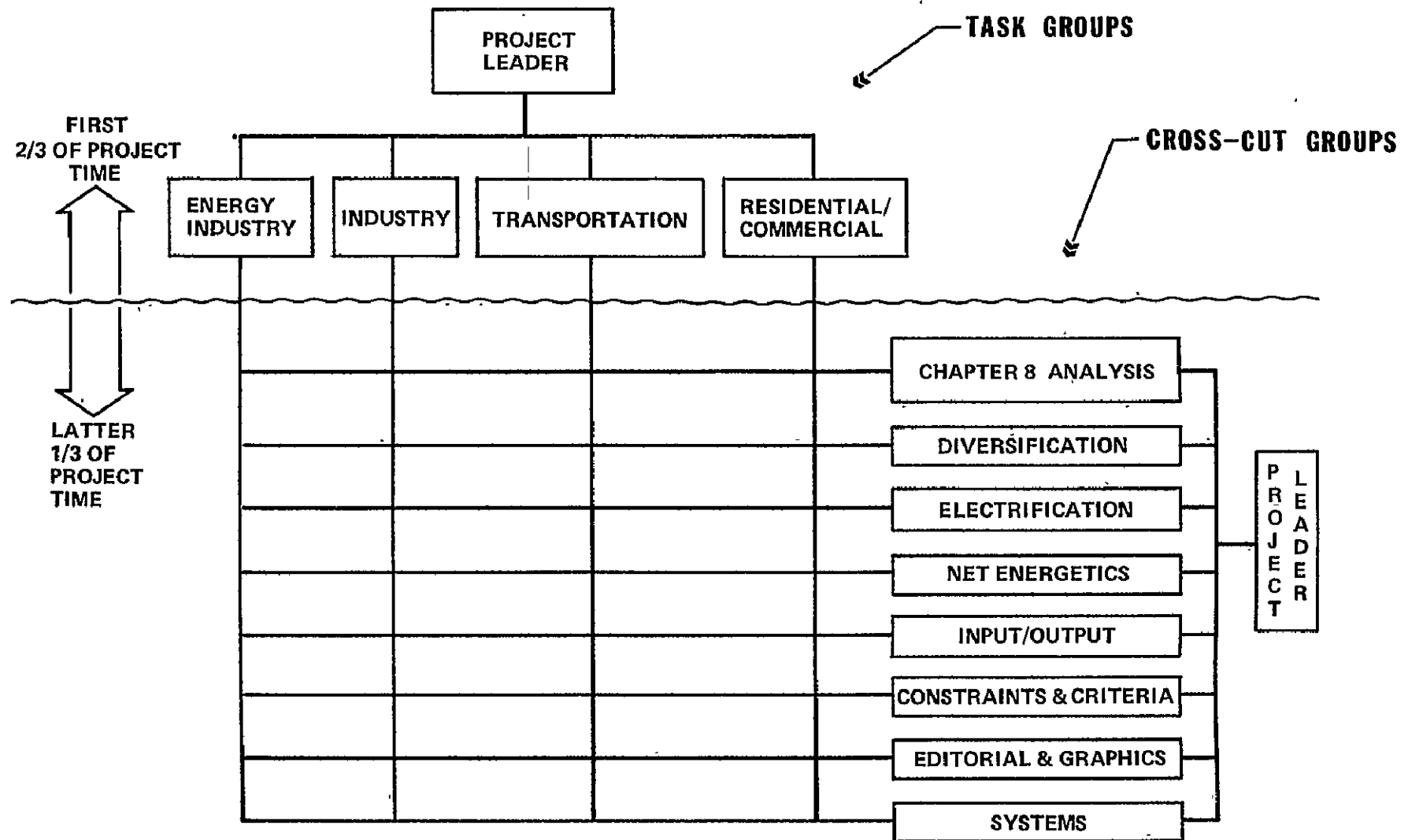


FIGURE 3.2.2-1  
ECASTAR MATRIX ORGANIZATION

organization and indicates the "cross-cut" task groups developed during the last 1/3 of the time. These "cross-cut" groups examined the issues of electrification, diversification with respect to energy sources, citizens' actions for energy conservation, and evaluated impacts for some specific energy conservation actions under the heading National Energy Conservation. In addition, one "cross-cut" group developed an integrated examination of energy conservation actions in the energy industry, residential/commercial, transportation and industrial sectors of the U. S.

### 3.2.3 STUDY PHASES AND OBJECTIVES

The ECASAR study was conducted in two phases -- the Systems Design Phase and Strategy Phase.

#### System Design Phase

The objective of this phase was to identify conservation actions, assess these actions, and perform limited systems integration of the actions with feedback to the objective. The energy system was divided into four sectors -- energy industry, industry, transportation and residential/commercial. Conservation actions were developed for each sector. The actions ranged from material changes to substitutions of new sub and sub sub-systems as well as altered operational procedures and altered use patterns in each sector.

The actions in the systems design phase are classed initially as conservation if the principle effect is in one of three categories -- efficiency, substitution for more valuable fuels or curtailment of demand. It is important to remember that the phrase "principle effect" is qualified by the need for a thorough assessment to determine if the action does lead to energy conservation.

The actions by sectors generally are defined narrowly and are technical or economic in nature. Thus, highly refined constraints and criteria are not essential. Furthermore, the number of actions was by necessity limited to a few in each sector which again did not lead to a list of highly refined criteria.

#### Strategy Phase

The objective of this phase was to identify sets of existing proposed or imminent energy conservation policy actions having a large potential for conservation. These sets which cross the sector boundaries constitute the strategies of electrification, diversification, and national energy conservation. The strategies were assessed as completely as possible within time and resource constraints.

The time frames for the strategies are roughly consecutive. National energy conservation is a near term (1975 to 1985) strategy, electrification is a mid term (1985 to 2000) strategy with the potential for being far term, and diversification is far term (2000 and beyond). These sets of actions display essentially all possible modes of conservation. Electrification is almost a direct outgrowth of near term substitution and has real potential for efficiency improvement. This is based on the potential associated with substitution of one activity in a sector for another by using electricity from a central station. The potential increases of efficiency with electrification and the use of waste heat are considered. Diversification is long term substitution of one form of energy source for another. Diversification may be necessary even in an ultimate energy economy such as an economy based on fusion. Diversification reduces the dependence of an economy on one source of energy and the expenditure of capital on one energy source. Diversification may lead to new export opportunities. National energy conservation addresses the near term and includes all modes of conservation. This strategy builds on recent history of intensive energy consumption using scarce fuels. The strategy is proposed by some as an alternative to deregulation of fuels in the U. S.

### 3.2.4 CONSTRAINTS AND CRITERIA

The constraints and criteria of the study are numerous. Some are obvious, while others are subtle and recognized only after completion of the study. Many others are tacitly agreed upon and not listed. This section presents a partial listing and characterization of some of the constraints and criteria. The list is given in two forms -- statements of constraints and criteria and questions embodying constraints and criteria.

Some of the constraints and criteria are more flexible in their application than others. This flexibility depends on the ranking given to a constraint or criteria. The lower the ranking is, the greater the flexibility. The ranking is a reflection of the importance society gives to the technical, social, economical, environmental, legal and political constraints and criteria. An inflexible statement of a constraint is that actions must not be unconstitutional. A flexible but highly ranked criterion or set of criteria relate to "life style". The energy problem is a threat to current life style and hence this threat becomes a motivator for energy actions that permit "life styles" to improve or lead to minimal degradation. This criterion or set of criteria places the government and the citizens at odds when government tries to act for the common good, since any action has potential for depriving one group to benefit another. Government tries to obviate the adverse effects on a group through rewards, subsidies, or other compensatory programs or plans. The statements and questions relative to constraints and criteria can be listed under generic categories and stated generally. Each general statement or question leads to more specific statements or questions. The ECSTAR group has not developed an exhaustive list of specifically stated constraints and criteria in an explicit manner.

Rather, the constraints and criteria are implicitly contained in the tenor and writing of the report. Chapter 2 contains the large scale constraints on the subject of conservation.

The following is a list of statements and questions relative to constraints and criteria:

#### Statements

The study shall be confined to the U. S. economy but interactions with foreign economies shall not be neglected.

Federal and state laws germane to energy conservation must be considered. Those laws or regulations blocking a beneficial conservation action must be noted. If the proposed energy conservation action is not unconstitutional, then consideration should be given to recommending a change in the law/s and/or regulation/s.

Existing and proposed energy conservation efforts, economic, technical and social, within the legislative and executive branches of State and Federal government must be considered.

Parties at interest to energy conservation should not be overlooked. Identification of those who gain and those who lose must be included in the study. Losses must be minimized.

Present energy conservation actions in industry must be considered. ECSTAR proposed actions must not lead to sudden disruptions in the industrial sector. The disruptions of primary interest are productivity, employment and dislocations of business and industries.

"Life style" changes must be determined for any anticipated energy conservation action. "Life style" changes should be minimized as much as possible if the change means a degradation of "life style". Furthermore any change in "life style" should be orderly.

Capital requirements must be determined for anticipated actions and the selection of actions must be financially feasible. Financial feasibility should be considered in terms of U. S. gross national product projections and capital reformation.

Energy conservation actions must consider energy resources availability. Fossil resources should be conserved using the following priority -- gas, oil, coal.

All proposed energy conservation actions must be evaluated in terms of a net energy savings.

All energy conservation actions must consider environmental impacts and these impacts must be minimal.

The time frames for energy conservation should be

near-term	1975-1985
mid-term	1985-2000
far-term	2000 -

These time frames are stated on the fact that (1) energy systems are currently projected to 1985 with reasonable certainty, (2) energy conservation of immediate impact must be accomplished starting now and continuing through the present U. S. energy transition period, (3) the mid-term recognizes that any changes of the U. S. energy system beyond 1985 must be planned now and those changes will probably "buy time" for major changes based on technology around the year 2000.

### Questions

Does the action increase jobs, increase economic activity, lower costs, pay for itself, increase profits, stabilize energy supplies to the individual user, prolong usefulness of investment, encourage new investment, remove inconvenience, create a sense of security, enhance life style?

Does the action satisfy the needs for fuel in specialized forms, save certain fuels not necessarily BTU's, impact immediately or in the very near term (e.g., 0 to 3 years), decrease dependence on unstable supplies, increase supplies, prevent profiteering, level supply with time, recognize resource limitations in making fuel choices, increase environmental strain, increase perception of danger, decrease uncertainty about technical and economic feasibility of options, subsidize technical or economic performance, recognize geo-political factors in fuel sources or fuel choices, distribute shortages equitably, increase direct efficiency, reduce unnecessary end-use, penalize selected end-uses and end-use patterns, satisfy legal constraints or achieve variance?

Does the action optimize the system, solve the problem instead of altering it, save energy and other resources on a net energetics basis, remove potential sources of a future energy problem, preserve economic and technical incentives, preserve economic and technical strength for future major redesign of the energy system, establish a foundation of knowledge and experience in advanced technology, preserve economic strength to meet major social demands, promote development of industries and infra-structures less sensitive to fuel form and supply, increase the

stability, flexibility, and adaptability of the energy system, provide for the transition to the next generation of fuels and uses, increase reliable options, allow for alleviation and solution of problems of urbanization, distribute unavoidable impacts equitably?

Some of the user criteria questions relate to supplies of special fuels which depend on supplies of large volume products or supplies for non-fuel purposes or specialized end-uses. Natural gas is singled out immediately as having special non-fuel end-uses, and specialized clean fuel uses. Aviation fuels depend on the production in parallel of other transportation fuels which in turn depend on the production of unspecialized products like heating oil to compensate seasonal demand. Some inhouse electrical generation which indirectly saves oil or gas in turn depends on the need for coke and has attendant pollution problems.

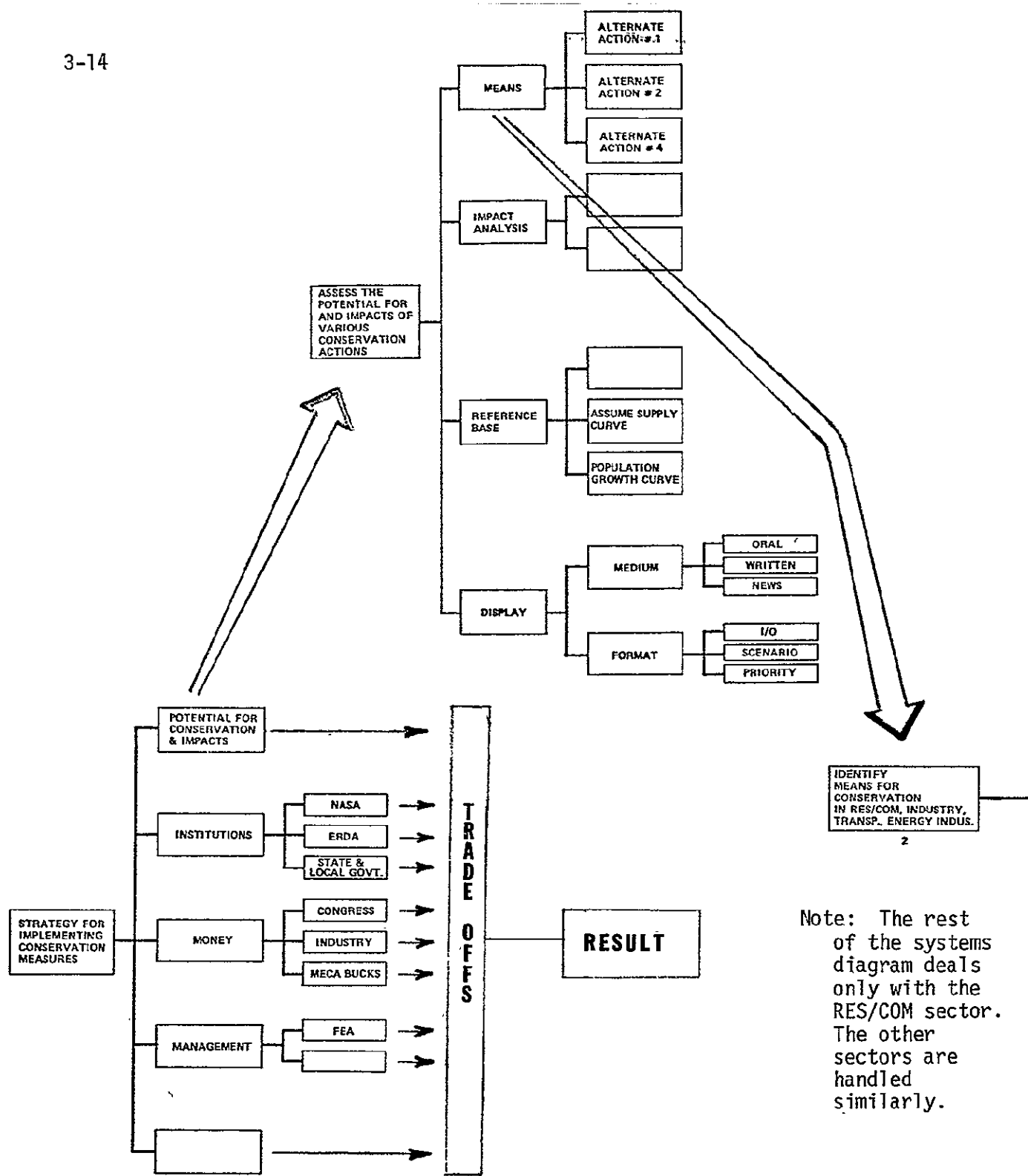
In summary there are few if any strictly technical or strictly time independent criteria in the energy system or in conservation. It will take some time and a totally new approach of imposing systems thinking to mold the energy system by engineering criteria. All the engineering notions of optimization interact with higher ranked economic and social criteria and always will.

### 3.2.5 REQUIREMENTS AND IMPACTS

The requirements for the systems approach of energy conservation were identified for the objectives of each phase of the study and these requirements in turn became objectives for sub-system approach studies. The requirements for the sub-systems approach studies became objectives of sub sub-system approach studies and so on. Figure 3.2.1-1 indicates the hierarchy of the studies. Figure 3.2.5-1 gives a total display of the process used in ECASTAR and the requirements. One sub-class of requirements for energy conservation means or actions is tangible in nature. These requirements with others constitute the fabric of the three strategies examined. The materials, capital and labor requirements are usually the tangible requirements of key interest in a study. The magnitudes of these requirements determine the impacts of the proposed actions on society and the economy. Impacts give rise to "bottlenecks" in achieving the actions and help society decide if the action or actions are worth the costs. ECASTAR develops some of the requirements through to the impacts as an example of what can be done to assess energy conservation.

### 3.2.6 TRADE-OFF

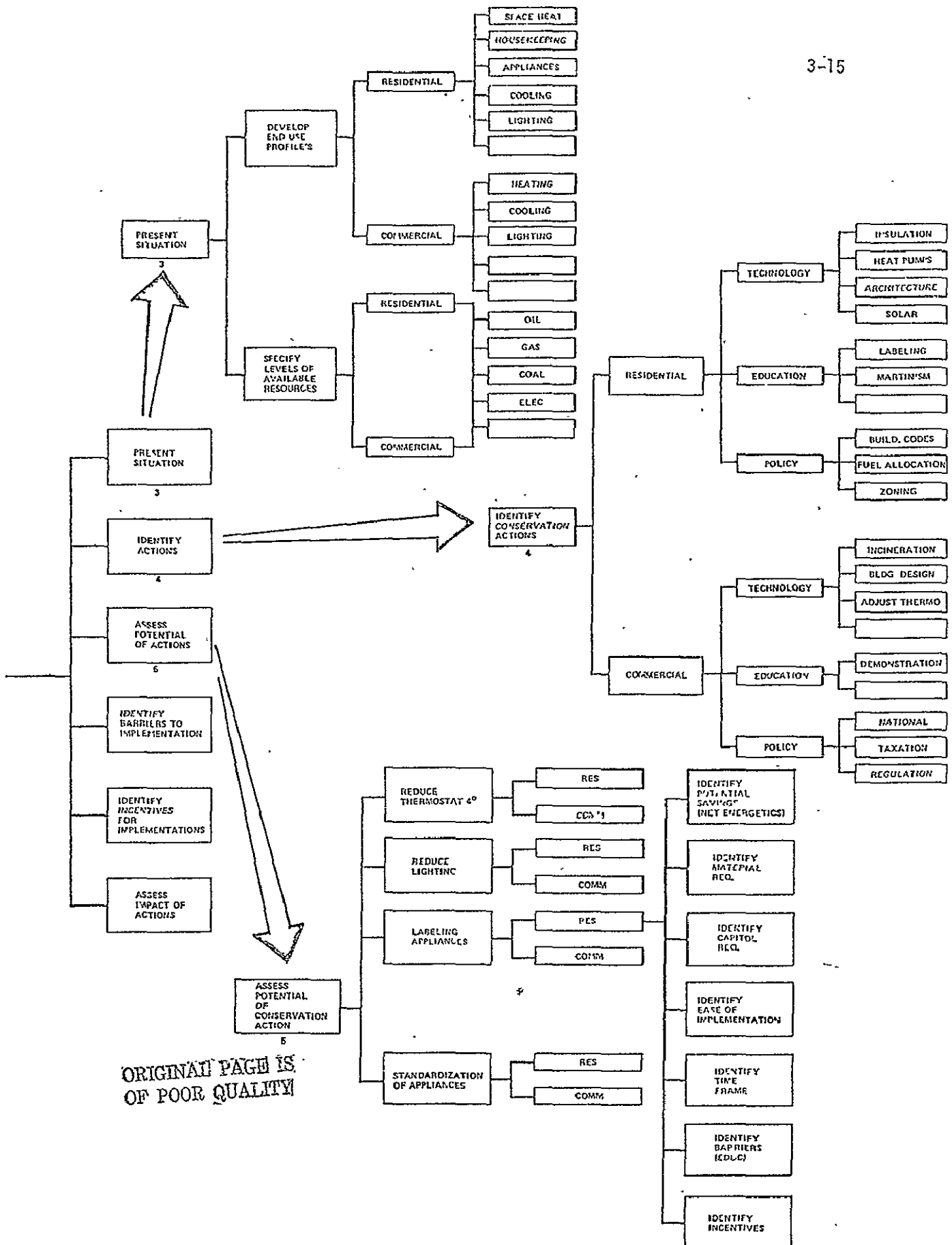
In a program with the goal of a single product, alternatives are examined and a set selected which is optimal in terms of the criteria. ECASTAR contains some examples of trade-offs but by far the greater emphasis is placed on other assessment methods.



ORIGINAL PAGE IS  
OF POOR QUALITY

FIGURE 3.2.5-1 ECSTAR SYSTEMS DISPLAY  
OF PROCESS AND REQUIREMENTS

Note: The rest of the systems diagram deals only with the RES/COM sector. The other sectors are handled similarly.





### 3.2.6 INTEGRATION

A particularly important feature of a mixed system is its integration with other major technical-social-economic systems. In a pure systems design the integration is almost assured because of the many stages of trade-off and feedback as the system is built up from the component level to sub-system levels ultimately to the systems level. In dealing with a scenario or strategy, there are similar large systems acting, such as the environment. The integration is not done in the small iterated construction steps but is left for the last step. This is not to say that scenarios and strategies could not be constructed from iterated sub-systems. It is just the fact that they are usually arrived at from different perspectives. In particular, each is imbedded in the present situation which contains very little in the way of well-integrated sub-systems.

Integration is important in assuring that the system has those features which are more than numerical performance. Such features are stability, adaptability, interface to systems to come, and optimization in qualitative areas.

### 3.2.7 FEEDBACK

The iterative feature of the systems approach has already been referred to in a previous section. There is another sense to feedback which is related to requirements and to integration. The requirements are neutral couplings of sub-systems on a very deep level. The integration process implied other sub-system interactions. The last sense of feedback to be mentioned is that interaction between sub-systems through variable characteristics of the sub-system. The residential/commercial and transportation sectors do far more than interact through energy supplies. They do far more than meet at the curb or property line. One sub-system determines many of the performance criteria of the other sub-systems. Many of these feedback topics are addressed. For example, how does the number of vehicles determine the placement and grouping of dwellings? How does the availability of gaseous, liquid, or solid fuels determine population distribution, manufacturing, consumer preferences? It is these large scale specific feedbacks by sectors which are the prime motive for the strategy phase of ECASTAR.



### 3.3 INPUT-OUTPUT ANALYSIS

The ECASTAR group sought to examine energy conservation, potentials, and impacts from as broad a perspective as possible. The group was concerned that energy conservation was being viewed in too narrow a context. Many studies have failed to investigate possible impacts on the industrial or national level due to preoccupation with the specifics of a conservation action. Preoccupation with one specific action prevents a clear total picture of energy conservation in its many forms. The potentials for conservation remain ambiguous.

Input-output analysis was seen as a tool which would allow the group to evaluate the multiple impacts of either a specific conservation action or a set of actions occurring simultaneously in an economy. The tool was modified in a way that would permit the tracing of both labor and energy flows. Thus an action which originated in one industry but impinged on all industries could be systematically monitored. One novel use of the analysis was in the identification of conservation targets of opportunity. The pinpointed "targets" were intermediate interindustry product flows which, while not being large in terms of dollar flows, were nonetheless large in terms of BTU flows.

Input-output analysis, in conjunction with ECASTAR's systems orientation, was successfully utilized in forming a blueprint of assessing jointly conservation in industry, transportation, residential/commercial, and energy supply sectors. This included identifying conservation potentials, assessing the impacts of conservation actions, and displaying the trade-offs which inevitably occur.

The group constructed the ECASTAR energy input-output matrix and used it to investigate the positive and negative aspects of impacts on the economy resulting from a conservation action or set of actions. The model uncovered material bottlenecks, potential labor shortages, and effective conservation actions. The results of the input-output analysis are presented in Chapters 8 through 11.

In preparation for these later discussions which use input-output analysis, an explanatory description of the tool is presented. The appendix to this section describes the procedure in more detail (see C.3.2).

In 1967, total output from the primary metals industry, Standard Industrial Classification Code, SIC code 31, amounted to a little over \$52 billion. Of that total, only two and a half billion dollars made its way directly to final product markets. By far the majority of this industry's output was purchased as an intermediate product by other industries. What would happen if output from primary metals decreased? Almost surely such an occurrence would have serious repercussions throughout the economy -- primarily by affecting production in other industries. Clearly, the ability to trace systematically the impacts resulting from a change in interindustry transactions becomes an important tool of analysis.

Input-output analysis, I-O, is a technique which permits a formal analysis of industry sales and purchases. In this section attention will be directed to a brief introduction to the technique. The application of this method of analysis to assessing impacts of conservation actions will be presented in Appendix C.3.2.

To highlight the salient features of I-O consider the following economy. In this economy there are only three producers; mining, manufacturing, and agriculture. Final markets consist of sales to consumers and the government.

The sales by any producer can be found by reading across the rows in Table 3.3-1. For example, the manufacturing industry produces total output equal to 50 units. Of that total, 20 units are sold to the mining industry, 20 units are purchased by manufacturing itself, 5 units are sold to agriculture, and 5 units are sold directly in final markets. A firm's total output must be apportioned between sales to other industries and sales to final markets. Table 3.3-1 is frequently called a transaction matrix. Normally units are expressed in dollars. Incidentally, gross national product, GNP, is the sum of sales to final markets. In this example GNP would be 35. GNP is not equal to the sum of total outputs, 150. That sum involves considerable double counting. Other useful information can be distilled from the transactions matrix.

Rather than reading across a row to find the sales of a producer focus on the entries in any column. Take the column headed by manufacturing. If one divides each entry in that column by the total output for manufacturing one obtains what are called the direct requirements for producing one dollar of manufacturing total output. For this example these are shown in Table 3.3-2.

The numbers have the following interpretation. To produce \$1 of manufacturing output the industry requires 30 cents of input from the mining industry, 20 cents of its own product, and 30 cents from the agriculture industry. These inputs account for 80 cents of the dollar of output. The remaining requirements are allocated to value added -- primarily employee's compensation and return on capital.

The direct requirements table conveys information which ranks the relative importance of all inputs which are used in production. Notice also that for the manufacturing industry to produce a dollar of output for final demand the output from the manufacturing industry must be at least \$1.40. Why? Because 40 cents of every dollar of total output from that industry is itself used as an input in the production process.

While it has not been stressed note that there are also direct requirements for the remaining industries. For example, to produce a dollar of total output in mining requires an input from mining of 20 cents. To be able to provide 30 cents of output to manufacturing

TABLE 3.3-1. SALES BY PRODUCERS: A TRANSACTIONS MATRIX

<u>Producers</u>	<u>Mining</u>	<u>Producers Manufacturing</u>	<u>Agriculture</u>	<u>Final Market</u>	<u>Total Output</u>
Mining	10	15	5	20	50
Manufacturing	20	20	5	5	50
Agriculture	5	15	20	10	50

TABLE 3.3-2. DIRECT REQUIREMENTS FOR MANUFACTURING

Units: dollars of input per  
dollar of total output

	<u>Manufacturing</u>
Mining	.3
Manufacturing	.4
Agriculture	.3

mining must produce output greater than 30 cents because like the manufacturing industry, mining uses some of its own output in its production process. Thus, there are a whole network of indirect requirements underlying the direct requirements table. Total requirements, direct and indirect, are usually also presented. The computation of entries in that table are more complex. This description is given in Appendix C.

Once the direct requirement's matrix has been computed, a variety of questions can be asked and evaluated. For example, if the output from primary metals were reduced by 10%, one could a) determine which industries would not be able to meet their final demands, b) determine which industries would be impacted first, and c) determine what the gap between previous and current total output would be and how, by substitution, etc. to narrow the gap. In another example, one could assume that growth in all sectors amounted to 4%. Given the new output levels and final demands would there be sufficient quantities of all inputs, including energy, to satisfy these new levels?

Analysis can also proceed on non-dollar dimensions -- if total labor and energy (in BTU's) requirements are known for all industries. The crucial assumption needed in shifting from dollar flows to labor or BTU flows is that the direct coefficients remain fixed. This is the usual assumption in input-output analysis. An energy I-O matrix can be very useful. For example, such a matrix would enable one to trace through the impacts of energy usage due to shifts in final demand or due to specific conservation measures like increasing energy utilization efficiencies. Shortfalls in energy may uncover bottlenecks and/or opportunities for conservation which may have been overlooked. Energy impacts may well be different for labor and dollar impacts. Thus, for any action considered it becomes necessary to examine what happens to interindustry transactions and final demand in terms of BTU, labor, and dollar dimensions.

### 3.4 ENERGY PERFORMANCE CRITERIA: NET ENERGETICS VERSUS NET ECONOMICS

The ECASTAR group recognized that one criterion for judging energy systems in terms of conservation is efficiency. This section represents a summary of the ideas expressed in Appendix C.4 of this report. The interested reader is directed there.

Efficiency is defined as the ability to produce a desired effect with a minimum of effort, expense or waste. Effort indicates the thermodynamic input to an energy system. Energy efficiency will be considered both in terms of the First and Second Laws of thermodynamics. The First Law states that energy in the total system is neither gained nor lost; it merely changes form. The Second states that during any process, energy degrades. In other words, the available energy or useful work capable of being extracted from an energy stream is less than what is available in an idealized sense. First Law efficiency can in general be characterized by ratios of energy out (BTU) to energy in (BTU).

The latter two quantities are determined by the actual forms of the inputs and outputs of the process, and the process itself. If one were to establish a true energy accounting system in a First Law sense, one would account for all energy "embodied" in all the materials involved with the process and the direct energy for the process. With the use of input-output analysis described in the preceding section, it is possible to approximate the direct and indirect energy inputs to a process. The application of the broadest First Law efficiency criterion is termed "net energetics".

Net energetics accounts for initial energy use (the analog of initial dollar cost), life cycle energy use (the analog of life cycle dollar costs) and the embedded energy in manufacturing and raw materials including energy thrown away in production and transportation.

Second Law efficiency can be characterized by the ratio of the minimum available work theoretically necessary to generate an output to the available work actually consumed in its generation. The application of the Second Law could be important to an energy accounting system. This application is left to future study. Much work is needed to evaluate energy systems in these terms. The implications of Second Law efficiency on the nature of the U. S. energy system as a segment of the overall economy are thought to be significant. However, net energetics shall be limited to first law efficiency in the sequel.

In contrast to accounting in thermodynamic terms is the more popular accounting in dollar terms. Two types of efficiencies will be discussed. The first is called first-cost efficiency. An energy system is relatively efficient in this sense if it has the smallest initial cost of implementation out of a set of alternatives. The second is life cycle cost efficiency. Life cycle cost combines first cost with the discounted flow of expected energy costs over the life of the system. An energy system is deemed life cycle cost efficient if it has the smallest life cycle cost out of a set of alternatives.

Related to the attempt to minimize effort or expense is the concept of waste. One might consider waste as the measure of how much effort and expense a process uses over its respective minimum. The

problem of identifying waste may be reduced to evaluating alternate inputs to the process or to evaluating the size and character of the rejected streams of energy and materials. One principal reason for actual efficiencies never matching theoretical ones is that the constraints of time, materials, money and markets determine the system's operating point. Within the system, there are various forms of waste that may be identified. They are not all inclusive nor mutually exclusive. They are mentioned to depict some important problem areas. One can consider outright energy waste as that consumption which can be stopped with little or no expenditure of labor, capital or other costs. Systems waste may flow from the types of production and consumptive devices which employ energy, the forms in which energy inputs are utilized and the failure to take into account the recycling potentials of the components of the systems. Some of these may be easily correctable, but others may entail a complete restructuring of present systems.

The three criteria for energy systems choices may be compared in their application to conservation actions. The status quo contains energy systems, and any move to substitute alternate systems must be assessed. Some actions may be efficient in a first-cost sense but not according to the other two. Actions efficient in the life-cycle sense are not necessarily first-cost and energy efficient. Energy efficient actions may be unattractive in both the first-cost and life-cycle cost sense. It is felt that the degree to which the three criteria are not consistent is the function of a faulty mapping between units of energy and dollars. This is in part due to the fact that energy prices do not reflect the true value of these resources to society in terms of their worth to consumers, the externalities associated with their use, and the approach of some of them to their ultimate limits.

As mentioned in Chapter 1, conservation implies substitutions at various levels of society. The performance criteria help to evaluate these substitutions. Appendix C contains the application of these criteria to both broad and specific conservation actions discussed in the sequel. It is hoped that the discussion in the appendix, coupled with the pioneering work at the Center for Advanced Computation at the University of Illinois and Research Triangle, Inc. in North Carolina, will provide policymakers with a new view of effective energy conservation actions.



### 3.4.1. EFFORT OR ENERGY MEASURES

The energy measure which is most often used when evaluating the performance or setting goals for technological improvement of engines, appliances, industrial processes etc. is energy efficiency which arises from the First Law of thermodynamics. The First Law may be stated as: Energy can be neither created nor destroyed, but only converted from one form to another. First Law energy efficiency is a comparison of the useful energy output of a process or system to the energy input necessary to obtain that desired output. Thus an increase in energy efficiency can be thought of as a decrease in the amount of energy (effort) necessary to produce a desired output.

When making comparisons between alternate ways of performing an activity or setting a goal for that activity in terms of energy efficiency the definition of the specific situation must always be carefully stated. That is, the efficiency that is being referred to must be defined relative to a system and a process. There are many efficiencies that can be defined for a given system and the choice of which to use often is the deciding factor of whether the system performance appears to be good or bad. For example, when referring to the efficiency of a power plant, a qualifying statement must be made as to whether the energy input is taken to be the raw fuel energy in or the heat input to the working fluid at the boiler. Likewise, the point of measurement and form of the energy output must be stated. It is the electricity at the bus bars, electricity delivered to end use, or total energy out of the system consisting of electricity plus the heat energy out in the cooling water. This concept must also be kept in mind when specifying standards of performance or desired increases in performance and when comparing two energy using systems or devices. An example is the setting of a goal of 20% increase in efficiency for a specific type of energy using consumer product. The definition of efficiency must be cast in terms of specific statements as to what the input and output energies are and how they are to be measured.

The First Law of thermodynamics states that all forms of energy are equivalent in that, when one form of energy disappears, an equal quantity in another form appears. The First Law makes no attempt to designate whether or not a system or process is ideal or to specify the direction the process must take. For all systems the First Law is a bookkeeping device to ensure that energy is neither created nor destroyed but merely changed in form. The Second Law of thermodynamics recognizes that all forms of energy are not equal in their ability to do work -- some forms of energy are more valuable than others. All real processes convert energy from the more useful to the less useful forms, i.e. energy is degraded in all real processes. For example, high-quality energy (fossil fuels, nuclear energy, hydropower) is converted to other forms of high quality energy (electricity, work, high temperature heat) or low quality energy (low temperature heat). As an example of the difference in grade of energy, consider the energy contained in the cooling water from a power plant. Although this water

contains a great deal of energy its quality is low. That is because of its very low temperature very little useful work can be obtained from it. The First Law of thermodynamics cannot reflect the degradation of energy from high grade to low grade during an energy conversion process since it is satisfied if energy is merely conserved. A measure of the performance of a system which does reflect the degradation of energy is the Second Law efficiency or effectiveness. The effectiveness is defined in terms of available energy which is actually consumed in a process unlike energy which is conserved. "Available energy is the maximum portion of energy that could be transformed into useful work by processes which reduce the system to a state in equilibrium with the earth and its atmosphere" [Obert-63]. The effectiveness is defined as:

$$\epsilon = \frac{\text{increase in available energy of desired output}}{\text{decrease in available energy required to obtain output}}$$

That is, it is the ratio of the least available energy that could perform the task to the available energy actually consumed in doing the task with a particular system or device. The utility of the Second Law efficiency is that it emphasizes processes where there is a mismatch between the grade of the input energy and the grade of the desired energy output. For example, although the First Law efficiency of a gas furnace is 70%, its effectiveness is only about 13%. Since the desired output from this system is low grade energy (low temperature heat) the low value of the effectiveness is an indication that high quality energy has been used to obtain a low quality result or that low quality energy input could have been used to obtain the same desired result. A good example of a process that would have a high effectiveness and use low grade energy (e.g. from the cooling water mentioned above) would be to use waste heat from a power plant or industrial process for space heating. A more subtle example would be an indication that more emphasis should be placed on improving combustor performance in a power plant than on improving the condenser performance.

The effectiveness is an indicator of how well a specific device executed a specific task relative to how efficiently that task could have been performed by an ideal (best possible) device. It is also a measure of how much improvement is possible. Maximizing the effectiveness will minimize energy consumption for a given task. The distinction between First and Second Law efficiencies may be extremely important in that it could indicate where funds should be allocated for research and development aimed at increasing energy performance of systems and devices.

The concept of energy efficiency can be extended to include all the energy inputs necessary to obtain a good or service, that is net energetics. Net energetics is an energy accounting scheme whereby the total energy cost (energy inputs in BTU, kwh, etc.) of providing a good or service is considered. Only when we know the total energy cost of a good or service can we determine the energy conserved by consuming one good or service instead of another, or by substituting a new technology or process for another. Energy inputs (or cost) to provide a good or service are classified as direct or indirect. Direct energy is that consumed at the end use

### 3.5 AN EXAMPLE OF THE METHOD: TECHNOLOGY APPLICATION

The application of the methodology to the U. S. economy by sectors using the input/output analysis matrix and other means identified several targets of opportunity for energy conservation. These targets of opportunity represent areas where technology may be applied to effect conservation through increased efficiency or substitution. The group chose targets where NASA technology was applicable since the information resources of NASA were immediately available, NASA has an obligation to transfer its technology, and feedback on the applications suggested was available from NASA personnel. The NASA example is just that and it should be stressed that other sources of technology can be tapped using the ECSTAR methodology. As will be pointed out it is necessary to understand a socio-economic-political problem like energy in its entirety before applying technology. Technology applied without a priori assessment of impacts on society as a whole can lead to ridicule for technology and a disastrous result. Technology applied wisely can be a servant to man the inventor.

One of the objectives of NASA as specified in the National Aeronautics and Space Act of 1958 is:

"The most effective utilization of the scientific and engineering resources of the United States, with close cooperation among all interested agencies of the United States in order to avoid unnecessary duplication of effort, facilities, and equipment."

The Agency has been fulfilling this charge in many areas of technology including some pertaining to energy conservation. Examples of NASA technology and programs that have a bearing on energy conservation are:

work in the areas of materials, selective coatings and the technology of heating and cooling which directly bears on the efficient collection and use of solar energy;

new technology in the areas of aerodynamics, structures, materials and power generation that is being applied to the development of windmills for power generation through a NASA-NSF program;

solar cell expertise gained over years of experience is being applied to the problem of reducing the cost and increasing the efficiency of solar cells for direct conversion of solar energy to electricity;

experience in hydrocarbon fuel chemistry and combustion applied to the development of low-cost techniques for production and collection of organic material and its conversion to fuel;

study aimed at using hydrogen as a central station or portable fuel to reduce pollution and increase efficiency.

The learning process for both NASA and American industry in the transfer and utilization of advanced technology has taken about 10 years. Several years were required for a backlog of technology to accumulate and for operational experience to be amassed. The rate of successful transfer is quite high now and should grow rapidly. Energy related problems in particular will be a strong impetus for adoption of new technology because needs are urgent, old ways of doing things are being critically examined, and new methods and devices are receiving research support which entails strong technological support to bring a product to the commercial stage.

An example of a specific area that has been identified as having great potential for energy savings is improvement of combustion efficiency. The combustion process is widely used throughout every sector of the economy -- in industry for heating process steam, in the energy industry for heating of steam for power production, in transportation for internal combustion engines and for space heating in the residential/commercial. An estimate of the potential for energy savings by improvement of combustion efficiency is that in just the process heat for industry a 5% improvement would result in a savings of 1 million barrels of oil per day by 1985. A detailed study aimed at identifying specific problem areas in combustion was conducted by the American Physical Society. [APS-75-2] The APS identified three areas in which research was needed:

- experimental combustion diagnostics,
- combustion modeling, and
- emulsified fuels for combustion systems.

NASA's expertise pertaining to these areas includes extensive experience in combustion and fuels research, as well as specific and general applications of materials, components, subsystems, display technology and experience with complex modeling. This technology and experience may be applicable to the types of specific problems which have been identified and this may be one area where a real contribution could be made. Other areas where NASA may supply support technology or design expertise are:

- systems analysis and computer modeling studies of energy usage in buildings and district systems, including thermal response and aerodynamics studies;
- heat pump research and development to extend the useful temperature range and explore the areas of solar assisted and ground water assisted heat pumps;
- research on rechargeable batteries;
- aerodynamic studies of automobile and truck air drag;

system studies to optimize efficiency using criteria based on the Second Law of thermodynamics;

establish precise environmental standards, land and water use programs to guide construction of nuclear plants, oil refineries, coal mine development and coal conversion;

develop new environmental monitoring and control programs using satellites as a means of establishing large area interactions with the goal of maintaining or decreasing present maximum allowable pollutant levels while increasing usage of high sulfur fuels;

development of an advanced flight control system for aircraft that could increase the efficiency substantially by reducing the weight;

studying topping cycles to increase the overall efficiency of power plants;

evaluating Rankine and Brayton energy conversion technologies developed in the aerospace program for possible use in automobiles;

applying their expertise to the problem of obtaining energy from the ocean temperature gradients.

There are other areas in which space technology is being applied to present day energy problems, but undoubtedly there are many more yet to be identified where technology can be applied to effect energy savings.

In order to identify additional areas in which technology could make an impact on energy conservation, it is first necessary to understand the problem in its broadest context. ECASTAR endeavored to do this by employing a systems approach to look at all aspects of the problem as well as the interrelationships between them. ECASTAR characterized energy conservation in terms of constraints and criteria that included the social, political, and economic implications and connections. That is, ECASTAR attempted to provide an interface between the technological world, in which problems and criteria are defined in technical terms, and the real world which technology must serve. The effort looked at energy conservation in its social, economic, political environment rather than from the narrow viewpoint as an application of new technology.

This study was aimed at identifying targets of opportunity for energy conservation that were of importance to all parties in a sector of the economy, and which offer a potential for conserving energy through an application of technology as well as social, economic or political means. ECASTAR demonstrated techniques for essential clarification of the overall problem such as input/output analysis and net energetics as well as the

systems approach and impact assessment. The group sought to identify areas in which relevant detailed studies should be conducted to identify specific problems whose solution would result in large net energy savings. Once specific problem areas have been identified, existing technology or areas of technological expertise must be identified that are relevant to the specific problems. Next, the existing technology must be communicated to researchers, developers, support industries and producers of consumer products or the technology can be developed by a group with experience and expertise in the relevant area.

## CHAPTER 4. CONSERVATION IN THE ENERGY INDUSTRY

The basic supply and utilization problems faced by the United States are described. Actions which might alleviate the domestic shortfall of petroleum and natural gas are described, analyzed and overall impacts are assessed. Specific actions included are coal gasification, in situ shale oil production, improved oil and gas recovery, importation of liquid natural gas and deregulation of natural gas prices. These actions may be weighed one against the other as alternate techniques of alleviating or overcoming existing shortfalls.

### 4.1 INTRODUCTION

Specific sectors included within the energy industry are electrical power production and transmission, oil production and processing, natural gas production, uranium mining and production and coal mining. Also included are a number of developing technologies such as natural gas liquefaction, coal gasification, coal liquefaction, shale oil development and solid waste gasification. Electric power generation is of such significance that it will be discussed separately in Appendix J. Similarly, those developing technologies which are not commercially feasible at this time are described separately in Appendix K. Basically, each of the energy industries is to some degree in direct competition in supplying energy to industrial, residential, and commercial consumers. although features of individual sources may preclude particular fuels in specific applications.

In 1973, it was found that 23% of the total energy used in the United States came from coal, 41% from oil, 30% from natural gas, 1% from nuclear and 5% from hydroelectric. In reviewing proven reserves the imbalance in utilization is startling; coal comprises about 95% of all proven fossil fuel reserves. At 1972 consumption rates, coal reserves would last for 800 years, while oil reserves are sufficient for only 8 years and natural gas reserves for only 11 years. These numbers are somewhat misleading in that they represent only known reserves and not those yet to be discovered. Nevertheless, they do illustrate in an approximate way the overall relations. Coupled with this problem, and in part due to unequal utility of fossil fuels, is that of an energy shortfall for specific fuels. Production rates from U. S. sources of both oil and natural gas are below demand. As a consequence, oil must be imported, often from unreliable sources. Since transoceanic transport of natural gas is more difficult, the demand is simply not met, and supplies are interrupted. The approach within the industry in solving the problem is to curtail industrial users of natural gas and to examine alternate sources. The shortfall in oil is being met largely through imports and to some extent through conversion to coal. It is thought that conversion to coal will be increased in the future as further technological development introduces economical techniques of burning coal cleanly. In the short term, significant pollution problems, together

with environmental concerns over strip and deep mining, will hamper rapid shifts to coal. A number of developing energy sources including solid waste utilization and shale oil are presently under consideration. These are of differing significance in terms of commercial potential, but each offers an alternative to scarce and dwindling reserves of oil and gas. Shale oil is especially attractive in that U.S.G.S. indicates that U. S. resources of shale oil are almost twice those of coal. [Fisher-74, 31] The future for nuclear power development is not clear at this time. Nuclear power plants are not being constructed as rapidly as expected, and the issue is presently in abeyance as intervenor issues are debated. Should these problems be satisfactorily resolved, nuclear power may be expected to fulfill a major portion of national energy needs.

In view of the reserves of coal and shale found in the United States, it is clear that no shortage of total energy resources exists; the problem is one of a shortage of domestically produced oil and gas. The resources are here for a solution; the technology, policies and equipment are not.

Section 4.2 outlines actions by industry undertaken over the past 20 years and indicates which actions tend to increase energy supplies. Section 4.3 describes recent government actions which have affected energy production. Several actions which are frequently proposed to increase future energy supplies are analyzed and discussed in Section 4.4. These actions are coal gasification, in situ oil production from shale, improved techniques for oil and gas recovery, importation of LNG and deregulation of natural gas prices. Each action is similar in that it serves to increase the supply of petroleum or petroleum substitutes. Moreover, each action may be implemented in the near term so that a significant impact may be expected prior to 1985. They may, therefore, be viewed as competitive approaches to the energy problem, each vying for a share of the capital available for energy development. A comparison of these proposals is presented in Section 4.5.

## 4.2 CONSERVATION STATUS

Table 4.2-1 lists some of the technology changes which have occurred in the energy industry which have influenced conservation. Actions stemming from government and actions resulting in substitution are not included. Thus, this table refers to conservation by increased efficiency.

The substitution status was outlined in Chapter 2. The opportunities to substitute fuels are an outgrowth of policies which depleted fuels with smaller resource bases first. Thus, the U. S. cannot be proud of its chance to conserve by switching to coal and/or nuclear.

In general, significant efficiency gains have occurred in most areas of the energy industry even in a period of declining real prices for energy. Most of the inefficiencies are driven by consumer demand or mandated environmental protection requirements.



TABLE 4.2-1. CONSERVATION STATUS -- INCREASED EFFICIENCY IN THE ENERGY INDUSTRY

	<u>COAL</u>	<u>OIL</u>	<u>GAS</u>	<u>NUCLEAR</u>	<u>ELECTRICITY</u>
Resource Extraction	+ stripping + long wall mining	+ imports + enhanced recovery - finding rate	+ imports - LNG storage - nuclear stimulation		
Transportation Distribution	+ slurry lines + covered trains	+ evaporation prevention	+ larger pipelines		+ EHV, UHV lines + higher distribution voltages + lower corona losses - longer transmission lines
Conversion	+ combustion efficiency	+ refinery efficiency gains + control of product mix	+ improved yields in petro chemicals	+ greater fuel burn up factors + plant operating factor + conservative rating of cores	

A [+] indicates an increased supply or an increased efficiency of recovery or utilization, a [-] indicates the opposite

TABLE 4.2-1. CONSERVATION STATUS -- INCREASED EFFICIENCY IN THE ENERGY INDUSTRY

	<u>COAL</u>	<u>OIL</u>	<u>GAS</u>	<u>NUCLEAR</u>	<u>ELECTRICITY</u>
Resource Extraction	+ stripping + long wall mining	+ imports + enhanced recovery - finding rate	+ imports - LNG storage - nuclear stimulation		
Transportation Distribution	+ slurry lines + covered trains	+ evaporation prevention	+ larger pipelines		+ EHV, UHV lines + higher distribution voltages + lower corona losses - longer transmission lines
Conversion	+ combustion efficiency	+ refinery efficiency gains + control of product mix	+ improved yields in petro chemicals	+ greater fuel burn up factors + plant operating factor + conservative rating of cores	

A [+] indicates an increased supply or an increased efficiency of recovery or utilization, a [-] indicates the opposite

### 4.3 GOVERNMENT CONSERVATION STATUS

As mentioned in Chapter 1, government and the energy industry have had a long-standing relationship. State governments have instituted "prorationing" policies to prevent the "rule of capture" on jointly worked reservoirs in the hope of preserving natural drives. Wellhead prices of interstate natural gas have been regulated. Coal miners are being given compensation for hazardous health conditions. Public utilities (service) commissions have regulations on utility rates.

The legal restrictions common to all sectors of the energy industry (which are also common to many other industries as well) involve anti-trust regulation, health and safety regulations, land use and siting regulations, environmental standards and taxing policies.

Anti-trust regulation puts limits on the vertical and horizontal integration in the industry. This is an important problem since entry into this industry entails extremely large fixed capital investments. Health and safety problems have basically centered around coal mining accidents and black lung disease. Land use problems occur in siting power plants, refineries and transmission lines. Environmental problems occur with refinery discharges, acid drainage from deep mines and topographical disruptions from strip mining, power plant air pollution and/or thermal discharges, aesthetic issues, and land use concerns. Taxing policies have been controversial. Fossil fuel production has until recently carried with it a depletion allowance. This meant that 22% of the resource value was deducted from taxable income each year of the producing life of the well, even if more than 100% was eventually deducted. Other taxing policies have included investment tax credits and deduction of taxes paid to foreign governments from U. S. taxable income.

In summary, the government has intervened strongly into the industry's activities. Some of the measures are directed towards conservation. Many of the important measures at various levels of government are listed in the respective Appendixes. New government actions are being proposed currently, and it is part of the task of this group to evaluate a portion of these in terms of energy conservation. The result of this analysis is displayed in Appendix I. The government is very interested in developing a consistent policy that optimizes the net benefit to society. The energy industry is a particular target because of the widely discussed pricing practices in firms with large fixed capital investment and diminishing average and incremental (marginal) costs.

### 4.4 ACTIONS

In an overall view of potential for energy conservation in the energy industry, a number of actions stand out as especially pertinent in that near term implementation is frequently advocated. In each case, the technological problems appear manageable, economic potential is judged favorable, and development is commonly considered to require simple legislative, executive or industrial adaptation. A number of such actions are considered in Appendix D to determine their impacts and whether such actions could be implemented in the proposed time frame. The essential features of such activities are described in sections 4.5.1 through 4.5.5 below.

#### 4.4.1 COAL GASIFICATION

Present and projected shortages in natural gas have led to several alternative methods of supplementing of gaseous fuels. Coal gasification technology has reached the point where plans for commercial plants are being implemented, and permit applications are under government review. Six 250 mmcf/day plants are presently on order [Pollaert-75] with American Lurgi, and a total of 29 plants of various types and size are under study. [CA-75,94] The Lurgi plants have a sufficient operating history to be considered present technology items, and construction of these units presents no major technical problems.

A crash program to build coal gasification plants has been estimated to be able to produce up to 3 trillion cubic feet of pipeline quality gas per year by 1985. [PI-74-3-107] Natural gas production in 1973 was 22.6 trillion cubic feet, and production is not expected to rise significantly over the next decade. Synthetic pipeline gas production could reach 10% of the total supply by 1985 and could reduce oil imports by 500 million barrels per year. This represents 25% of the oil imported in 1973. [Ford-74-28]

Manufacture of the Lurgi gasifiers and associated equipment is not envisioned to be a major problem. [Pollaert-75] The vessels are designed for operating pressures of only 450-525 psig so that pressure vessel construction is well within the range of current technology. (Nuclear reactor vessels are constructed for pressures in the 1000-2000 psig range)..

While the process development and manufacture of the equipment appear manageable, other problems are unresolved. Government regulations on natural gas pricing preclude pricing structures based on mixed natural gas and synthetic pipeline gas (SPG). Intrastate natural gas has recently sold for \$1.20 to \$1.90/mcf at the wellhead, whereas SPG is estimated at \$2.50 to \$3.50 at the plant gate. While a mixed product price would appear competitive with oil, the higher priced SPG may not be marketable alone. The heating value of oil is such that oil at \$11.00 per barrel is economically equivalent to pipeline gas at \$2.00/mcf. It is not clear to what extent the residential and commercial sectors would choose to buy gas at the higher price; certainly there are some convenience features associated with gas which might continue to make it desirable. It should be noted that any future reduction in foreign oil prices might upset market conditions significantly. The risks in such a venture are enormous. Capital costs for the pipelines, plants and mines are estimated at \$30.75 billion. Unless the venture is guaranteed in some way, perhaps by a floor on oil prices, it is unlikely that adequate quantities of capital can be raised.

Environmental concerns have also presented a major obstacle to plant development. In general, gasification plants require extensive strip mining and enormous water resources. In the semi-arid regions where plants are proposed, it is not clear to what extent the land can be reclaimed. Moreover, diversion of water to mining and gasification

processes may seriously deprive existing agricultural areas. Large-scale introduction of mining and gasification into these areas would significantly alter the pattern of life, transforming agricultural and range land into industrial centers. There is sufficient opposition to such change to bring about numerous attempts to block development of gasification sites. The Sierra Club has been successful in blocking development in the North Platte River area until a multi-state environmental impact statement can be prepared and reviewed. This study has been estimated to take a minimum of two years, and further delays may follow as new questions are introduced. It would appear that a pattern may be developing in which interveners may seek to prevent such development through a series of injunctions. The procedure is similar to that used by groups in opposition to nuclear development. Unless fundamental changes are brought about in the method of licensing, it is doubtful if the process can provide a significant impact prior to 1985.

#### 4.4.2 IN SITU SHALE OIL PRODUCTION

Shale constitutes one of the nation's largest sources of fossil fuel; it seems reasonable, therefore, that its potential be carefully explored. In situ methods of shale oil production show distinctive promise for cost effectiveness. Moreover, Occidental Oil Shale Corporation has testified that a production level of 1 million bbl/day is achievable by 1980. Allowing some lee-way for additional technical problems, a goal of 1 million bbl/day of shale oil by 1985 has been established for this action.

At the moment, the nature of technological problems are not altogether clear. Occidental, the only company now active in in situ recovery, has successfully extracted oil from three experimental sites and has a commercial size project under way. Its primary interest is to demonstrate economic feasibility. To do so will require that a number of yet undisclosed technological difficulties be resolved. Although Occidental has not yet publicized its results, the following requirements are a reasonable estimate for a 50,000 bbl/day project (assuming 20 bbl/ton shale source).

Manpower	1,200
Construction costs	\$ 250 x 10 <sup>6</sup>
Operating costs	\$ 60 x 10 <sup>6</sup> /yr
Steel	60 x 10 <sup>3</sup> tons

Net energetics which give credit for crude oil, coke, ammonia, and sulfur produced but deduct for mobile equipment, energy, hydrogen reformation, process heat and electric needs show a favorable net energetics balance of 10.5 (output/input). [PI-74-9,87] If the energy required to produce the steel used is included, this figure reduces to 10.4. Other

factors such as energy requirements for disposal, grading, explosives, and sundry other items can reduce this further to 8.9. Additional considerations such as transportation requirements and environmental restoration will result in even further reduction. Potential savings from a 50,000 bbl/day operation would be  $2.9 \times 10^{12}$  BTU/day or 2.12 quads/yr discounting energy costs. The final net energetic gain reduces this to an actual savings of 1.76 quads/yr.

Although in situ shale processing does not present the kinds of demographic environmental problems that surface retorting does, the impacts are still severe. Native flora will be destroyed by removal and tramping. Labor requirements and concomitant population shifts will still be extensive. Consequently, water and land for residential use will be needed. Spent shale disposal will present a problem, and the prospects of leaching of alkaline materials and consequential contamination of ground water will have to be guarded against.

Successful in situ retorting of shale will depend largely on the results of Occidental's investigations. Sufficient data to draw a definitive conclusion should be available by Fall, 1975. At this point the program appears to be viable.

#### 4.4.3 IMPROVED RECOVERY TECHNIQUES FOR OIL AND GAS

This action is a conservation measure in the simple sense that it increases the efficiency of utilization of a resource by extracting a larger percentage from known deposits. Next to management of the well itself, management of the reservoir is the key to profitable production with a long producing life. Aside from the logic of recovering as much oil as possible from known deposits to reduce the exploration risks and first costs, enhanced recovery impacts directly on any policy of finding substitutes for imported petroleum.

Enhanced recovery of oil and gas is a partial substitute for imports, shale oil, coal oil and gas, and exotic portable fuels or hydrogen generation. There is some potential for tapping resources such as heavy crudes and tar sands which might otherwise remain unused. Tertiary methods such as in situ combustion would transfer technology to other extraction processes such as shale oil. The technology and know-how would also be of great value for export or for assistance programs to developing nations. Environmental and social impacts per unit of energy are generally small with enhanced recovery methods.

In this discussion all the statistics will be based on [PI-74-2].

The gains in enhanced recovery methods will come from oil reservoirs, heavy crude reservoirs, and tar sands. Present technology of a pre-embargo vintage recovers an average of 31% of the oil in the reservoir. The recovery is estimated to rise to 39% under the assumption of

\$7/bbl oil. Recovery may exceed 50% in some fields with prices at \$11/bbl. The model parameters for a typical well give a simple picture of the effect of advanced recovery on well life. The primary life of the well is taken as 5 years and the secondary and tertiary lives as 5 and 20 years, respectively, at much reduced production levels. The implication is that most wells are on secondary recovery now, and many are beyond the help of secondary recovery. In the era of stable oil prices when economic incentives for advanced recovery were weak and the technology was not very advanced, massive shut-ins of wells occurred. There is limited potential for reopening wells once shut-in.

The overall potential for secondary and tertiary recovery techniques is large. As a percentage of oil already produced plus an addition to new production, enhanced recovery is large both in total (as much as a 30% addition to the recoverable fraction) and large in near term impact (as much as 20% of domestic production by the 1980's). This oil produced by enhanced recovery constitutes a contribution to fuels needed to ride out the transition to other fuels with larger resource base or to intermediates requiring development.

The status of enhanced recovery technology is good and improving. There is a well developed industry and supplier chain and a pool of trained personnel. The training and education programs exist for expanding the manpower base. It has been proposed in the Department of Interior's 5-year R & D Programs (June 74) that \$300 million be spent on enhanced recovery research and development. A further amount has been allocated for other programs such as heavy crudes and tar sands.

The technology of secondary recovery is basically water flooding (90%) and other injection schemes (10%). Tertiary recovery involves more elaborate flooding programs using more expensive media or more complex cycles of operation. It also includes combined mechanical (explosive or hydraulic) working with chemical or thermal stimulation.

The principle requirements of enhanced recovery are an attractive threshold price and the requisite investment. The threshold price can be estimated from additional investment per barrel of added reserves. The estimated secondary recovery investment today ranges from \$0.32 in the Gulf to \$0.96 in Alaska per barrel added. Tertiary investment is estimated to range from \$0.80 to \$1.68 in the different oil regions. Enhanced recovery costs are projected to double or more by 1988. [PI-74-2,III-22] Present Congressional thinking would allow for some fraction of old oil to be sold at a ceiling price of \$7.50 relative to the \$5.25 ceiling and bona fide tertiary recovery projects to have a \$8.50 ceiling. This pricing structure proposal is discussed more fully in the chapter on HR7014. There is the intent to eventually erase the price differential on domestic oil except for OCS and Alaska.

The material requirements specific to enhanced recovery are minor. In general they represent the same distribution of materials as primary production. Sheer size of the requirements is not a deterrent to the programs visualized in Project Independence. Water use is very small

compared to the consumption in processing fuels. Also the water or fluid drive is usually made up of whatever is on hand: brine, CO<sub>2</sub> and some natural gas liquids. Tertiary recovery will require specialized chemicals. The demand for these and other supporting goods and services will expand the infrastructure of well service companies and create some new opportunities. There is also a large material recycle program inherent in enhanced recovery work. These old wells supply a good fraction of the pipe and equipment needed to implement advanced recovery.

The impact picture for enhanced recovery is in general favorable especially for secondary projects. Tertiary recovery, particularly unproven methods such as in situ or microbiological methods, lack either history or assessment of impacts. Prolonging the life of a production site contributes a proportionate environmental load each year, but to counter this, it reduces the expansion of oil production into new territories. The initial drilling and production periods have greater environmental impacts than the long term stable operation phase. Initiating new recovery methods introduces a transient load on the environment. Insofar as enhanced recovery substitutes for other intermediate fuel forms, such as shale oil and coal conversion, it should be credited with large net savings in environmental impacts. Since enhanced recovery potential is still small compared to our long term fuel needs, the impact of these other energy conversions is delayed, not prevented. The economic life of communities and firms tied to old oil folds will be prolonged.

The actions discussed above leave out one important alternative, nuclear stimulation of gas. The recent experience with this method has not been encouraging. Real problems exist with yield, seismic hazards, entrained radioactive materials, cost and net energy return. Opposition is growing to the point of passing state laws forbidding nuclear explosions.

#### 4.5. THE GOVERNMENT DEREGULATES NATURAL GAS PRICES

The justification for this action stems from the regulation of interstate gas prices by the Federal Power Commission at prices below equilibrium levels. This legislation can be enacted immediately. It will raise the prices of natural gas (NG). The American Gas Association has an elaborate computer simulation model which estimates gas prices and production for 1975, 1980 and 1985 assuming that gas prices are deregulated this year. They assumed other prices constant, except for a 5.5% inflation rate over time. The jump in gas prices takes place immediately and then simply follows inflation. Old gas prices are assumed to follow current contractual agreements. In terms of a BTU equivalent to \$11/bbl oil, new gas prices are expected to rise to \$1.96 this year, \$2.56 in 1980 and \$3.19/Mcf in 1985. National average prices projected (including old gas) are \$.55, \$1.56 and \$2.66 respectively. Total marketed gas is projected to be 18.3, 22.7 and 29.2 Tcf respectively. These figures imply continuing shortages of 1.6, 4.0 and 1.8 Tcf respectively. Demand for gas is expected to rise over the period, but imports and syngas are expected to increase supplies.



In actuality, the prices of oil, coal and electricity should increase. Demand for (supply of) these commodities will go down (up), and the degree is measured by the own and cross price elasticities of each (see Section 1.2.1 above). The actual manpower, capital and other requirements are related to expanding supplies of NG, oil and coal as a response to higher prices.

Increased fuel prices not only erode purchasing power directly, but lead to increases in the prices of goods for which they are important inputs. This may make American goods less attractive abroad, but decreases our dependence on foreign oil and gas. Higher prices, however, are a difficult burden to the poor.

Higher fossil fuel prices also may make alternative methods (e.g., tertiary recovery, shale, OCS, solar heating, etc.) relatively more attractive. They promote conservation by generally causing people to reduce use of direct fuels, to implement more efficient devices such as heat pumps and compact cars and to substitute non-scarce fuels such as coal in industry and electricity from coal or nuclear fuels in the residential/commercial sector.

Quads saved are very difficult to estimate since the interplay of several market forces and other government edicts are uncertain.

#### 4.5.5 IMPLEMENTING OF LIQUID NATURAL GAS (LNG)

The justification for this action is that it has a potential in solving some high demand problems by supplementing domestic natural gas supplies and to provide gas during periods of normal (base-load) use. The details of the technology, costs, potential and impacts of implementing this action are presented in section E.4.5.4. The technology of importing LNG involves the following:

Install gas liquification facilities in oil producing countries, which do not have much local demand for NG that is produced with oil, to convert NG to LNG,

Ship LNG by heavily insulated cryogenic tankers,

Install regasification and storage facilities in the U. S. (importing country).

LNG technology has been used commercially in the U. S. for more than 30 years; technology was initially applied to provide supplemental gas during periods of high demand. More than 30 plants are presently in operation to provide LNG when large demands for heating gas exceed the pipeline capacity during the coldest days of the year. Foreign LNG was first utilized during the winter of 1968-69 when the LNG equivalent of

about 150 million cubic feet of gas was imported from Algeria by Bosten Gas Company. The price ranges in dollars per 1000 cubic feet between 1975 and 1980 are expected to be:

LNG from Alaska to U. S. West Coast	1.50-2.18
LNG from Canada and Venezuela	1.00-2.20
LNG from Eastern Hemisphere	1.00-1.89

It is estimated that the contribution of LNG imports in 1985 to the total U. S. natural gas will be 1.6 trillions of cubic feet (about 5.4% of total U. S. natural gas supply).

Among the major considerations in LNG importing is the large capital investment required for ocean tankers. Moreover, long-term operating experience is still an extremely rare commodity in the LNG business. One should also note that the small number of LNG facilities installed in foreign exporting countries makes it much easier for production to be interrupted than is true for crude petroleum and export. Environmental concerns are with the human health and safety impacts of any accidental spill or fire associated with transporting huge amounts of LNG.

In conclusion, the benefits of LNG lie in the fact that it has an octane rating well above 100 without the addition of anti-knock additives; it is clean burning and produces minimal air pollution; its specific energy per pound is 15% greater than gasoline and it can be used as an engine coolant before it is burned as a fuel.

## CHAPTER 5. CONSERVATION AND THE INDUSTRY SECTOR

Excessive energy consuming patterns and the substitution of energy for manpower have been encouraged in the past not only by "cheap energy" but by governmental policies (regulation) and by a changing economy and society. Growing energy consumption can be directly related to the substantial changes that have evolved in the lifestyle of the U. S.; for example, productivity in industry has increased with the growing substitution of machines for labor, resulting in fewer man-hours and shorter working weeks.

Today, things are different. Industry is faced with increasing fuel cost and little hope of relief in the near future. Over the past few years some industries have recognized the inevitable shortage of certain types of fuel and have planned accordingly. However, most industries have been hard hit by the rising fuel costs; consequently, conservation is one way to help solve the problem.

Six of the most energy intensive industries were chosen for study in the industry task group. After studying conservation actions within each industry the actions were grouped under three broad categories: (1) increased combustion efficiency, (2) process improvement, and (3) good housekeeping. Approximately 7.5% savings have already been accomplished in industry by implementing good housekeeping measures. Under the increased efficiency category, decreasing the excess air in the combustion chamber from 20% to 10% results in a fuel savings of approximately 1% (0.15 quads in 1980 and 0.18 quads in 1985).

Based upon some rather tenuous assumptions and Gyftopoulos' data, it was estimated that approximately 2.18 quads could be saved in 1980 and 2.57 quads in 1985 by installing cogeneration facilities in 50% of industry. [PFE-74] Obviously there are monumental obstacles to the implementation of this action in the area of regulation, fuel supply, and utility corporation.

Under the category of process improvement, a significant savings in energy may result from installation of air preheaters. Regenerative air-preheaters can result in a 10-15% increase furnace efficiency which represents a 15-25% fuel savings (2.3 to 3.9 quads in 1980 and 2.7 to 4.5 quads in 1985). These savings are based on the fact that the combustion process requires about 70% of the projected fuel consumption.

It is important to note that the fuel consumption projections used were very low (23.2 quads in 1980 and 25.9 quads in 1985). Since the calculations are based on these projections rather than historical growth projections, the estimated potential savings may be low. However, in the case of preheaters it was assumed that preheaters would be installed whenever possible (estimate would be too high).

Several major industries have potential for energy savings by recycling -- aluminum (0.2 quads), steel (1 quad), glass (0.006 quads), paper and cement (0.08 quads). The major obstacle in this area appears to be reliability of supply. In addition to these broad categories, some conservation actions are included under individual industry discussions. Finally, a non-inclusive list of conservation actions is included.

A limited discussion of some of the impacts, barriers to implementation, and suggested incentives is included. Impacts in the political, economic, social, and environmental areas were identified. For example, one of the actions discussed -- cogeneration -- has impacts, both positive and negative, on each of these areas. Prior to implementation of this action the Federal Power Commission would have to make decisions concerning the regulation of electricity generated by industry. The most probable arrangement would involve utilities in an intermediary role in which they might purchase electricity from industry to sell to their customers. Since utilities already switch electricity back and forth using their grid network, the mechanics of such an action are less of a problem than convincing utilities that such an action is advisable. Even though the potential savings is large due to the fact that efficiency is more than twice as great when the waste steam is utilized, industry may be reluctant to step into this new role of electric generation with its accompanying problems. In general, industry has in the past preferred to purchase electricity and let the utilities worry about fuel supply and operation and maintenance problems. The possibility of a manpower shortage, in terms of the engineers needed to implement these conservation actions, needs to be explored.

Many of the regulations concerning environmental standards not only increase consumption of energy but also compete for capital needed to implement the conservation actions. The effect of large capital demands by industry on the capital market should be investigated. If capital is not available at reasonable interest rates, then budget cutting may result in a reduction in potential energy savings or other impacts, such as decreased employee raises, travel expenses, R&D funds, etc. These are only a few of the impacts that will have to be identified and assessed before conservation actions are implemented.

## 5.1 INTRODUCTION

As the largest energy consumer, the industry sector has a great potential for total energy savings with small percentage changes. An attractive feature for conservation efforts is the concentration of energy use in a few industries which provide a focal point. The prospects of conservation are enhanced by centralized management structures which can make the decisions for action and by localized energy activities which ease the implementation of the actions.

In assessing the potential for conservation in industry, six highly energy intensive industries have been singled out as targets of conservation opportunity. Considered together these industries accounted for 80% of the manufacturing energy consumption in 1967. These industries are food and kindred products, paper and allied products, chemicals, refining, stone, clay and glass, and primary metals. The Standard Industrial Classification (SIC) scheme is followed in the data collection and analysis. There is a capsule description of each industry in Appendix F.

Approaching conservation at the process level leads to consideration of process improvement, increased combustion efficiency, and general energy housekeeping. The immediate impacts of these actions may be less energy used and lower energy costs. The impacts would be localized and there would be longer term impacts. The conservation actions are carried forward ultimately to final consumption. The really potential catastrophic impacts occur if final demands are inopportunately altered. Drastic changes in the structure of consumption may set off reverberations throughout all industries. The magnitude and severity of the secondary impacts of the auto slump should be convincing.

As an alternative, only that energy which was utilized in the production of that industry's final demand would be charged to that industry. Under this accounting procedure, the energy used to make steel for automobile production would be charged to the automobile industry. Here the focus is on the final product -- that part of industry production which ends up as part of aggregate consumption. In terms of the GNP this is the relevant part of industry production. Following this accounting scheme, the industries which are "targets of conservation opportunity" change. Now, rather than focusing on primary metals, emphasis should be centered on the transportation, machinery and electrical machinery industries.

Whether the targets of opportunity are determined by looking at the intermediate products (primary metals, chemicals, etc.) or by looking at final demand (transportation, etc.), the potential for conservation may be misrepresented and underestimated unless the interdependencies are accounted. Examples of the assertion are given in Appendix E.

The assessment of the potential energy conservation in the industrial sector was chosen as the industry task group's objective. The assessment activity was organized by using a system diagram to display the interaction between the various activities undertaken by members of the group. A system and subsystem diagram is displayed in Section E.1.

## 5.2 CONSUMPTION STATUS

Consumption of energy for the six most energy intensive industries for 1967 and 1972 is shown in Table 5.2-1. The historical picture generally indicates an increase in energy use with the exception of primary metals. Energy intensive industries generally have centralized facilities for energy use and some flexibility as to primary fuel use.

Since the industries are unique, each has a specific consumption profile. The fuel use by type for each industry is presented in Table E.2.7-1 in Appendix E.2.

## 5.3 CONSERVATION STATUS IN INDUSTRY

Since industry historically has used about 40 percent of the energy used in the U. S., it seems likely that there would be a large potential for savings in that sector. Since the six energy intensive industries consumed 85 percent of the energy used by industry in 1971 [PI-74-8,3], these will be examined in some detail with respect to the conservation potential and current conservation status in Section E.3.

In general it has been estimated that large quantities of energy can be saved in the industrial sector because past policy has been to build and operate plants in the cheapest manner possible. Given the "cheap" energy of the past, most industrial operations have been large energy consumers and much of the energy has been wasted. Industry is now evaluating energy use in terms of economic savings.

There are varied estimates of the potential savings of energy in industry. [NAS-74,51] estimates that 20 quads by 1985, assuming historical growth, would be saved through materials management alone.

### 5.3.1 SCENARIO PROJECTIONS

Projected energy use under the three scenarios, historical growth, technical fix, and zero energy growth considered by the Ford Report [Ford-74], is given in Table E.3.1-1, Appendix E.3. The estimated savings of the technical fix over the historical growth is 10.2 quads by 1985 and 29.4 quads by 2000. The savings of the zero energy growth over the technical fix is estimated to be 2.1 quads by 1985 and 14.7 quads by 2000. See Tables E.3.1-2 and E.3.1-3 in Appendix E.3. [PI-74,172] estimates that the potential savings brought about by increased efficiency in industrial processes is 1.5 quads/year by 1985 with oil at \$11/bbl.

TABLE 5.2-1 CONSUMPTION STATUS

Consumption of energy for the six most energy intensive manufacturing industries for 1967 and 1971. The numbers are in quads and are from [EEA-74,1-30]

	1967	1971
Food and kindred products	.77	.92
Paper and allied products	1.16	1.31
Chemicals and allied products	2.59	2.78
Petroleum and Coal products	2.56	2.95
Stone, clay, and glass products	1.23	1.37
Primary manufacturing	4.08	4.03
All manufacturing	14.77	15.94

Fuel use by type is presented in Appendix E.2.7. Consumption data obtained from other studies and reports are included in Appendix E.2.

### 5.3.2 POTENTIAL CONTRIBUTIONS OF RESEARCH AND DEVELOPMENT TO INDUSTRIAL ENERGY CONSERVATION

The potential for contributions from research and development (R&D) to industrial energy conservation is generally believed to be quite large. There is agreement that energy savings as large as 20 to 25% per unit of output are possible through developing such technology as more efficient machines and new, low energy processes. The difficulties in implementing such results are discussed in Appendix E.3.8. A methodology to overcome these difficulties is displayed on Figure E.3.8-1.

The salient features of this figure are requirements I-IV which are the following:

- I - Identify High Energy Users
- II - Identify Technology Needs for Energy Conservation
- III - Assess Potential Energy Conservation Technology
- IV - Assess Impacts of the Technology if Implemented.

Satisfying requirements I and II above indicates that there is a large potential energy savings achievable through use of sophisticated existing technology (particularly NASA's). The major industrial energy consumers need more efficient combustion technology and better sensors for process control. Both are NASA technological strengths. Introduction of oxidizers in industrial combustion processes as is done in rocket systems offers potential for large energy savings. A 5% efficiency improvement in 25% of industrial combustion systems will result in over a 0.3 quads saving in 1975. Details are discussed in Appendix E.3.8. A partial listing of applicable NASA-developed sensors is given in Table E.3.8-1. It should be noted that insufficient time was available to the Design Group to finish requirement III.

Requirement IV, impact assessment methods, have been developed by the task group as a whole. Estimates of energy savings in a single industry due to specific technological developments must first be conducted. Then impact assessment, done on U. S. industry as a whole, must also be executed through the input-output techniques described in the preceding sections. Energy savings in one industry should be traced through all industry interactions to establish impacts such as total industrial energy savings. Other important impacts which may result from this analysis are changes in final demand for products and employment. Thus, complete research and development strategies with well defined benefits (and accordingly, high probabilities of success) can be developed.

In conclusion, it seems there are many opportunities for sophisticated technology in general and NASA technology in particular to satisfy technical needs which will bring about large scale industrial energy savings. Unfortunately, current NASA plans do not call for aggressively exploiting this area.



## 5.4 GOVERNMENT ACTIONS

Government actions have major effects on energy usage, prices and availability in all sectors of the U. S. economy. One program speaker [GT-75] noted that all U. S. energy prices are set on legal statute rather than cost of production. State regulation of natural gas prices is one example. Another example is the Emergency Petroleum Allocation Act (EPAA) of 1973 which sets prices for "old" crude and will expire August 31, 1975. Quantitative prediction of the impacts of "old" oil decontrol are listed in Appendix E.4. It seems clear that energy prices affect industry in two ways: (1) energy prices are part of the manufacturing cost (hence price) and, as such, influence demand for any industry's output and (2) prices consumers pay for energy also influences demand (e.g. automobiles). Therefore, energy prices affect industrial output, industrial employment, GNP, etc.

Federal legislation is also pending which will directly affect industrial energy usage and energy efficiency standards. At least three bills have been introduced which will require industry to: (1) furnish energy consumption information to the federal government and (2) implement plans to reduce energy usage per unit of output. The capital requirements for achieving large scale energy reductions are discussed in the following section in this chapter.

Another major government action is providing funds for research and development of energy usage. The principal agencies are ERDA (Division of Inter-industry Programs) [LS-75] and the National Bureau of Standards which has already prepared several guides to industrial energy conservation (EPIC Program [EPIC-75] and the Waste Heat Management Manual).

Other legislative influences on industrial energy use are state and local laws. Most existing legislation of this type causes excessive energy usage and is not conducive to producing energy conservation. [GT-75] Future state and local legislation may produce energy conservation by such means as requiring power plant siting so that industry will be able to use plant steam.

In summary, government actions influence and regulate industrial energy and conservation as much as any other factor.

## 5.5 CONSERVATION ACTIONS

Conservation actions in the industrial sector can generally be grouped into three broad categories: (1) increased combustion efficiency, (2) process improvement and (3) good housekeeping measures. Another important type of conservation action is reducing demand by changing end use patterns. This type of conservation action is discussed in Section E.2.

### 5.5.1 CONSTRAINTS -- AN OVERVIEW

In considering the three broad categories of actions, certain constraints and criteria were identified. Several of the constraints are imposed by industry itself. For example, industry, in general, treats conservation measures involving capital improvements the same as any other capital outlay. In addition, these conservation actions must have a pay-back period of less than two years. [EEA-74, 4-24]

Since capital dollars spent for conservation efforts will not be available for other improvements, such as environmental equipment and cleaning, there may be a conflict of interest in the allotting of budgeted money.

Several actions outside industry itself will have considerable effect on energy consumption, i.e., government regulations requiring a reduction in the quantity of lead in gasoline and the desulfurization of fuel oil. Thus, one can see that in some cases there is a direct conflict between environmental standards and energy conservation. The government should recognize that there may be a correspondingly large demand for capital if industry attempts to correct the situation in both areas simultaneously. A large demand for capital might result in rising interest rates and slow down the economic recovery of the country.

One of the most important constraints facing the manufacturing sector at the present is natural gas curtailments since gas accounts for roughly 40% of total consumption. Conversion away from natural gas toward other fuels has been taking place at a rapid rate. Since investments in this area are not available for conservation actions, the result is an energy penalty.

These and other constraints are discussed in Section E.5.1. In general, it has been found that since the Arab embargo, industry, by implementing many of the good housekeeping measures listed in the non-inclusive list of conservation actions found in Section E.5.5, has reduced energy consumption by about 7.5% compared to 1972 energy consumption levels [Wells-75]. The fact that these good housekeeping measures not only conserve energy but also require little or no capital investment while returning significant rewards in terms of money saved has made them extremely attractive in most instances. Consequently, most of the good housekeeping measures that could be implemented quickly have already provided significant savings in energy. The other two broad categories of actions are discussed in Section 5.5.2 and 5.5.3.

### 5.5.2 INCREASED COMBUSTION EFFICIENCY

Efficient firing of fuel is extremely important, as evidenced by the savings attributed to a reduction in excess air from 20% to 10% -- approximately 0.15 quad in 1980 and 0.18 quad in 1985 assuming that 70% of the energy consumption is involved in combustion, and using the Energy and Environmental Analysis, Inc. (EEA) projected consumption of 22.2 quads in 1980 and 25.9 quads in 1985. These assumptions are considerably lower

than historical growth projections, approximately 24 quads were used in the industrial sector in 1972 [NPC-74,27]. The projections of the EEA study assumed a 1.7% decrease in energy consumption per unit of output through 1980 and 1.9% from 1980 to 1985. Annual energy consumption growth rate for the manufacturing sector was assumed to be 3.1% per year which is slightly lower than the past trend of 3.2% per year.

Obviously, some conservation actions are assumed to be implemented in order to arrive at this decreased energy consumption per unit of output ratios in the future. However, using these lower projected consumption figures gives lower estimates of the potential savings available for each of the major conservation actions discussed in this chapter.

#### Power Generation VS. Purchased Power

Government regulatory attitudes are presently discouraging investments in internal power generation by manufacturing industries. The trend toward increasing reliance on purchased electricity is believed to be the result of industries' concern over the availability of fuel supply, in terms of natural gas curtailment and allocation priorities. Since they have a lower allocation priority than the utilities, industry is apparently letting the utilities worry about the fuel supply problem. Unfortunately, this trend toward increasing reliance on purchased power will result in the loss of significant opportunities for improving the efficiency of energy utilization.

The importance of this issue rests with the inherent inefficiencies associated with generating electricity at central power stations as compared with generating electricity on site and recovering the waste heat or using fuels to produce mechanical power. Whereas utilities on the average attain efficiencies of approximately 33%, the use of on-site electrical power generation combined with recovery of waste heat results in an overall efficiency of 60-70%, and the use of on-site steam generation for production of mechanical power can attain efficiencies of about 80%.

Using Gyftopoulos's [PFE-74,27] estimates for the potential for electrical generations per million BTU per hr., and other assumptions discussed in Section E.5.2 (50% implementation and EEA's projections), the potential for energy conservation by combining power generations with process heat is estimated to be 2.18 quads in 1980 and 2.57 quads in 1985. See Table E.5.2-1 for an estimate of potential saving by industry. Obviously, these are gross estimates since the 50% implementation-assumption has been applied to all industries. Some industries would have much greater potential for electrical generation while others would possess much smaller potential. In any case, the overall potential saving is significant, even assuming the extremely low overall consumption levels projected by the EEA study.

A gross estimate of the capital required to install cogeneration facilities in 50% of the manufacturing sector by 1980 is \$2.42 billion and the fuel cost, at .41¢/ KWh, would be \$2.07 billion. If the generated electricity were sold or used at the rate of 1.60¢/kWh, the return or the quantity generated would be \$8.1 billion (payback period of less than a year).

Since no consideration of interest rates, employee salaries, etc. was attempted at this point, this is an extremely simplified attempt to show that the economics of cogeneration may be encouraging even though monumental obstacles (federal power commission regulatory procedures, effect on utilities, assurance of fuel supply, etc.) must be overcome before any significant progress can be made. Some of these obstacles are discussed in Section E.5.2.

### 5.5.3 PROCESS IMPROVEMENT

Air preheating and recycling are the two conservation actions chosen to illustrate actions in this area.

#### Regenerative Air Preheating

Studies have shown that inclusion of a regenerative air-preheater system can result in a 10-15% increase in furnace efficiency, which represents a 15-25% fuel savings. [EEA-74, 4-26] This fuel savings represents 2.3 to 3.9 quads in 1980 and 2.7 to 4.5 quads in 1985 based on the EEA study projections. Estimates of capital investment based on Prengle's [PRE-74] total capital investment versus heat recovered plot (Figure E.5.3.1-2) range from \$.2 to \$.3 billion in 1980 and \$.22 to \$.34 billion in 1985. Estimated payback periods at various fuel costs indicate a payback period of less than 2 years.

#### Introduction of Previously Processed Materials Into the Production Stream

The total output of a manufactured product is the sum of primary and secondary production. Most frequently, the secondary production includes recycled materials as outputs from processing products (old scrap). Less frequent, but just as important, is the introduction of filler materials which are less energy intensive but which provide an end product with the desired properties. The secondary production takes advantage of the previous energy history of the material with the tendency to reduce the energy per unit total output.

Scrap can and will play a vital role as the raw material for secondary production in the aluminum, steel, glass, paper, and cement industries.

Recycling scrap aluminum with an accompanying energy savings of 0.2 quads is technically feasible and easily implemented if the supply is reliable. The major impacts are in the area of assuring the supply and the balance of payment problem -- the amount of ore (bauxite) imported is reduced.

Approximately a one quad savings can be obtained by recycling scrap steel. However, a large capital expenditure in the form of conversion from open hearth to the basic oxygen or to the electric furnace is required. Thus, even though the process is highly favorable from a technological standpoint, it will not be very easily implemented unless there is growth in the industry.

Recycling of glass within the glass industry does not look very promising even though approximately 0.006 quads could be saved through recycling. The obstacles encountered include a predicted reduction in the use of glass containers. One interesting idea in the area of glass recycling is the possibility of recycling scrap glass into the fiberglass industry. However, the net energetics and barriers to implementation, as well as the advantages accompanying such an action would need to be evaluated before such an action is seriously proposed.

#### 5.5.4 SPECIFIC ACTIONS BY INDUSTRY

A few of the actions being considered by specific industries are discussed in Section E.5.4. However, in some cases, certain actions could be applied to industry as a whole.

#### 5.5.5 CONSERVATION ACTIONS

A noninclusive list of some of the conservation actions proposed by various reports and individuals is included in Section E.5.5.

### 5.6 ASSESSMENT AND IMPACTS

As a result of looking at the potential for conservation in industry, certain areas requiring additional analysis have been noted. This section is an attempt to pull together some of the impacts that have been addressed in various reports as well as some that have been generated as the group worked on the actions. Obviously, all of the areas impacted cannot be identified by looking at the industrial sector in isolation. Most of the considerations deal with interactions between the industrial sector and the other sectors of the economy. A more thorough consideration of these impacts is presented in Chapter 8.

Estimates of future total capital requirements vary, but to Treasury Secretary William Simon, "... it is relatively clear that in coming years we will have to devote approximately three times as much money to capital investments as we have in the recent past" [Simon-75]. Since 1 1/2 trillion dollars was invested from 1962-1972, our future requirements will be in the neighborhood of 4 1/2 trillion dollars for the period 1974-1985. This capital is simultaneously earmarked for new plant and equipment, improving the quality of the environment, new construction, and the development of new energy sources; the capital is also earmarked for increasing productive capacity. In light of these demands on the capital, one might ask whether there will be a capital shortage and adequate funding to develop and implement conservation actions.

To put this assessment in perspective, compare 4 1/2 trillion dollars to a rule of thumb estimate of the supply of loanable funds for the period 1974-1985. Assuming a savings rate of 10%, and nominal growth at 5%, total savings for the period 1974-1985 would amount to a little over 2 1/2 trillion dollars [Santemaro-75]. One way to ease this deficit would be to increase the savings rate or change the output of some sectors. It should be understood, however, that the tradeoff would be a shift away from a consumption orientation.

Not all investment projects have equal implications. Those funds which replace plants, equipment, and increase productive capacity make it possible for the "economic pie" to increase in the future. Investments mandated by government, such as those aimed at promoting safety and securing a clean environment, do not increase total productive capacity. Investments for energy conservation fall somewhere in between.

Conservation investment made as a response to higher fuel prices and which have short payback periods will be more likely to attract the necessary capital than long-term investment projects. Relatively short-run investments provide a hedge against future variations in the rate of inflation. The cost of capital for conservation implementation depends on the accrued savings obtained through conservation. As fuel prices go up it becomes more attractive to use capital for conservation. In a tight capital market the increased use of funds for conservation will be accompanied with higher interest rates. This should not put a strain on industry conservation investment, as the returns from conservation are expected to still warrant paying the higher interest rates. However, investment for other uses may be sharply affected by higher interest rates.

Conservation actions imposed on industry by government which have long payback periods may reduce overall production and investment for new plants, equipment, and capacity. As operating costs increase, one can look forward to prices being passed through and reflected in higher retail prices. The reduction in plant investment, along with the destabilizing effect that these price changes have on inflation and final demand, suggest a much more uncertain future.

The economic feasibility of many of the energy conservation actions presently being considered is discussed in terms of a payback period of two years or less. In addition, the conservation action must be able to compete with other measures on the same basis. Although this constraint imposed by industry in general is understandable from the industrial point of view, not instituting such measures entirely on economic grounds is difficult to justify. For example, even though a conservation action may require a large capital investment resulting in a payback period of several years, its potential for savings and other advantages such as employment of additional workers should be examined and evaluated before the decision not to implement the action is made. If the action does indeed offer a large potential savings and has other positive impacts, then the possibility of an accelerated tax write-off rate to companies who cannot afford to implement this conservation action should be considered.

In many instances industry will be forced to commit large capital expenditures for pollution equipment. These capital expenditures will compete for capital funds that will be needed to implement conservation actions. For example, an article in the July 26, 1975 issue of the Tampa Times [TT-75] commented on the "relatively small" cost of environmental cleanup in the refining industry by 1983. The nonprofit Council on Economic Priorities estimated that the petroleum industry would have to install

pollution control equipment valued at \$3 to \$4 billion by 1983. The amounts needed for pollution control do not seem so huge in comparison to the nearly \$1 trillion (based on 1974 dollars) estimated by Chase Manhattan Bank to be spent on all capital investment in the refining industry over the next decade. "This industry deals in billions of dollars almost as a matter of course, and \$3-\$4 billion does not seem to be an impossible amount of money for the industry to raise." [TT-75]

The preceding statement concerning the "relatively small" cost of environmental cleanup could also be applied to the cost of energy conservation actions. In addition, the fact that saving energy means saving money makes these capital expenditures more attractive. However, environmental cleanup is already legislated and energy consumption reduction is voluntary. The question arises as to whether there will be a trade-off with some other area of the industrial budget. For example, the conservation measure may be implemented but R & D may be cut, or some employees may be laid off, or traveling expenses may be reduced. Obviously cutbacks in any of these areas will impact still other areas. A reduction in travel expenses, for example, may reduce the number of airplane trips a business may take -- a secondary impact which may or may not result in a reduction of energy consumption. If a company plane is involved, there may be a reduction in the number of flights but if the businessmen are using commercial flights, then these companies may be affected by a reduction in passenger loads, etc. Other areas where environmental restrictions may impact directly on energy consumption include:

Restriction of the use of lead in gasoline has resulted in increased energy use.

Reduction in coke production in the steel industry due to problems in meeting the air and water quality standards, which, in turn, has increased the use of direct oil injection in blast furnaces.

Desulfurization of residual fuel oil to comply with environmental regulations requires an equivalent of 3-4% of the quantity of oil processed.

Government requirements for sterilization and cleanliness partially offset trends towards lower energy requirements by adding to the already high consumption of energy for cooling and refrigeration [EEA-74,74].

Many of the government regulations imposed on the food and meat industries involve the consumption of large amounts of energy. Some industry experts believe a relative relaxation of the regulations would not affect meat quality. It is possible that recently proposed regulations will be postponed in an attempt to curtail rising industry energy requirements [EEA-74,7-6].

An impact area which has been used to manipulate industries' energy usage is the importation of energy intensive materials. The materials may be introduced at various times in the production stream, although the major use is at the beginning as raw materials (imported ore). This effectively reduces the energy used in the U. S. The impact of such importation has both political and economic impacts, heavy dependence on a foreign service and balance of payments. A major change in the steel industry may be the increased use of high grade foreign ore to reduce energy cost. The aluminum industry is already a heavy importer.

Recycling is often promoted as a major conservation action. A major obstacle is the reliability of discarded products being recycled. The removal of material from the waste stream is aggravated by diffusion. In order to insure reliability there must be major political and social changes.

One of the major actions discussed in Section E.3.2 was cogeneration of electricity. Higher fuel and electric costs could provide the needed incentive to increase the generation of electricity on site at plants having large steam loads. However, uncertainties about fuel supply could offset the effect of high fuel cost on combined steam/electric generation desirability. As discussed in Section E.3.2, assuring fuel supply might be an additional incentive to industry to encourage cogeneration. It appears that the economics favor the installation of such generating equipment if industry could sell the excess electricity generated.

Obviously, the implementation of this action requires considerable mediation between the utilities and industry. Much of this interaction will be discussed in Chapter 8.



## CHAPTER 6. ENERGY CONSERVATION AND THE TRANSPORTATION SECTOR

The United States possesses a remarkable transportation system which has given individuals a degree of mobility and the nation as a whole a capacity for movement of goods unequalled in history. But this system carries an energy price--approximately 25% of the nation's energy is consumed directly in the operation of the system. The technologies and methods for achieving a substantial reduction in this energy price are well known. Not so well known are the motivations which will lead to implementation of these technologies and methods. The focus of this chapter is to illustrate the present status and to explain why it is imperative that the most desirable of these technologies and methods be selected for implementation.

## 6.1 INTRODUCTION

The transportation sector is comprised of various modes: railroad, ships, truck, auto, pipeline, barge, and aviation. Each of these modes has certain inherent advantages for specific types of shipment, commodities, convenience, speed and energy consumption.

An intelligent appraisal of energy usage by the various modes in the transportation sector requires an understanding of the relative energy efficiencies, or conversely, the energy intensiveness (EI) of the various modes.\* Hirst has developed estimates of EI for various transport modes. [Hirst-73]. His study defined in detail historical changes in EI for the period 1950-1970. The contributions of changes in freight and passenger traffic levels, modal mix patterns, and individual modal EI's to changes in total transportation were computed. The EI's developed by Hirst for the year 1970 will be considered applicable at present.

\*Energy intensiveness (EI) is defined as BTU/ton-mile for freight and BTU/passenger-mile for passenger traffic. EI is the inverse of energy efficiency. It is important to remember that energy efficiency is a function of two factors: technical efficiency (capacity/BTU) and load factor (percentage of capacity utilized). For example: passenger-mile/BTU=seat-mile/BTU x passenger-mile/seat-mile.

The EI of the United States transportation system shows a historical increase across all modes with the exception of the railroads. The decline in railroad EI is a result of the conversion of the railroads from coal to oil during the decades 1940-1960. Figures 6.1-1 and 6.1-2 present the historical variation in EI for the various modes for intercity transportation of passengers and freight. Preliminary indications are that the EI's are relatively stable at this time.

#### 6.1.1 PASSENGER TRAFFIC

Passenger traffic and freight traffic show distinctive differences in modal usage. Intercity passenger traffic is carried primarily by automobiles with airplanes, buses and railroads making minor contributions. The variation in EI between these modes is pronounced, although not as great as for freight transport. As shown previously in Figure 6.1-1, buses and railroads are the most efficient modes. The trend in passenger traffic distribution among the modes has been to increase the percentage of traffic carried by the modes with the greatest EI. This, coupled with an expanding traffic base, has led to a 155% increase of energy use in intercity passenger traffic between 1950 and 1970. [Hirst-73]. Figure 6.1.1-1 shows the 1970 intercity traffic and energy distributions. Note that airplanes, because of their high EI, account for 10% of the traffic while consuming 22% of the energy. Urban passenger traffic displays gross differences from intercity passenger traffic in modal choice. Urban passenger traffic moves almost exclusively by car with a small and declining percentage carried by mass transit (either bus or rail). Figure 6.1-1 shows the EI for autos as compared to mass transit. Note that urban values for passenger EI are more than double the values for intercity EI values due to poorer vehicle performance and poorer utilization. Figure 6.1.1-2 shows the 1970 urban passenger traffic and energy distributions. Autos account for the bulk of both energy and traffic. The relative efficiency of mass transit is demonstrated by its smaller share of the energy distribution.

#### 6.1.2 FREIGHT TRAFFIC

Freight traffic EI's, as shown in Figure 6.1-2, for intercity traffic vary grossly by mode. Pipelines and ships are the most efficient modes, followed closely by the railroad. Trucks and airplanes are comparatively inefficient. The railroads experienced (and continue to experience) a steady decline in their percentage of intercity freight moved. This decline is offset by increases in truck, aircraft and pipeline traffic.

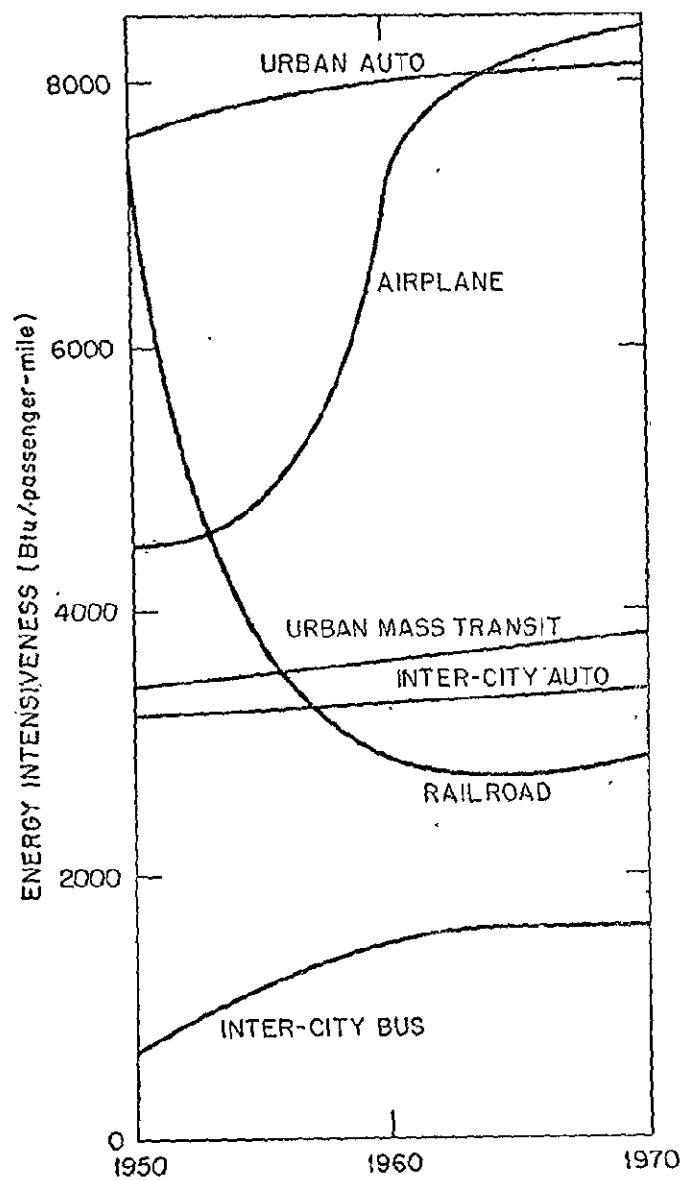


FIGURE 6.1-1. HISTORICAL VARIATION IN ENERGY INTENSIVENESS FOR PASSENGER MODES [Hirst - 73]

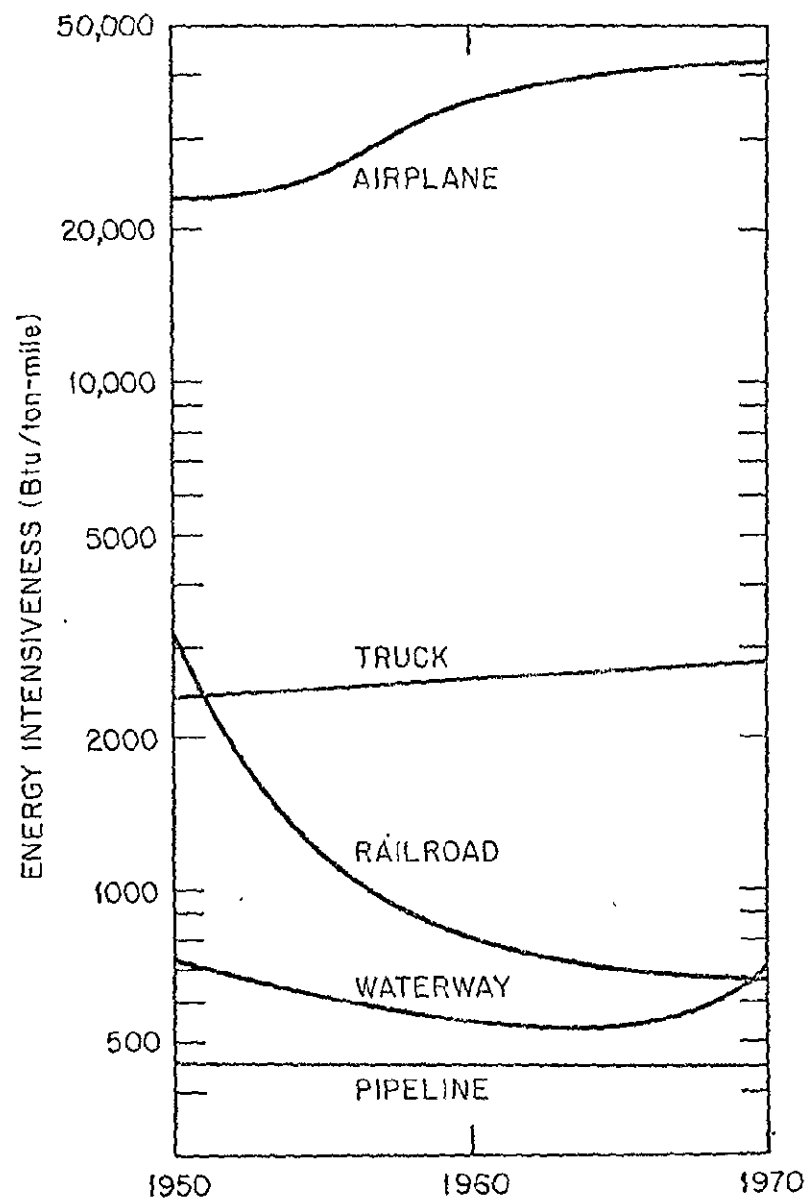


FIGURE 6.1-2. HISTORICAL VARIATION IN ENERGY INTENSIVENESS FOR INTER-CITY FREIGHT MODES, PLOTTED SEMI-LOGARITHMICALLY. [Hirst - 73]

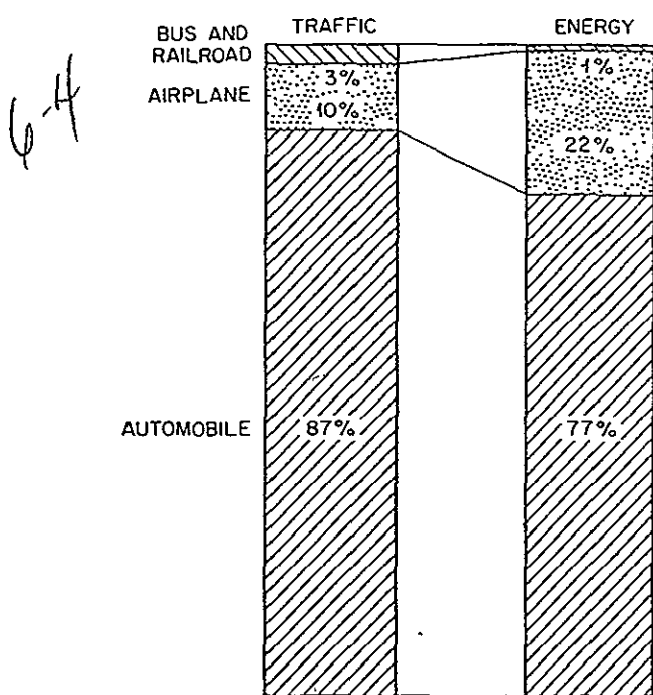


FIGURE 6.1.1-1. 1970 INTER-CITY PASSENGER TRAFFIC AND ENERGY DISTRIBUTIONS. [HIRST-73]

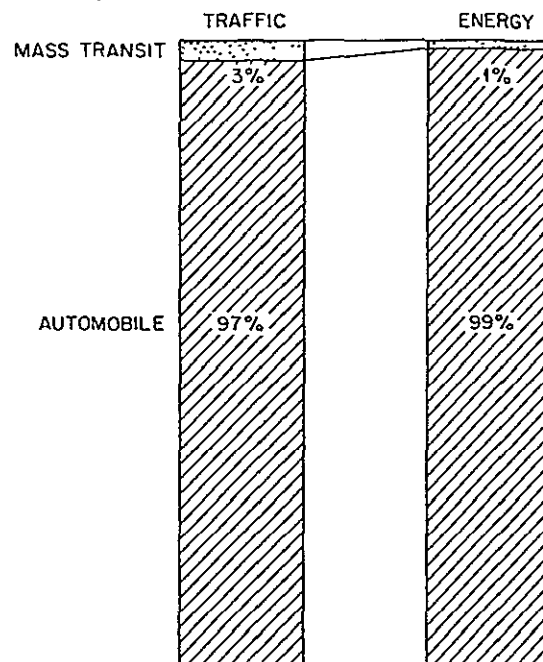


FIGURE 6.1.1-2. 1970 URBAN PASSENGER TRAFFIC AND ENERGY DISTRIBUTIONS [Hirst-73]

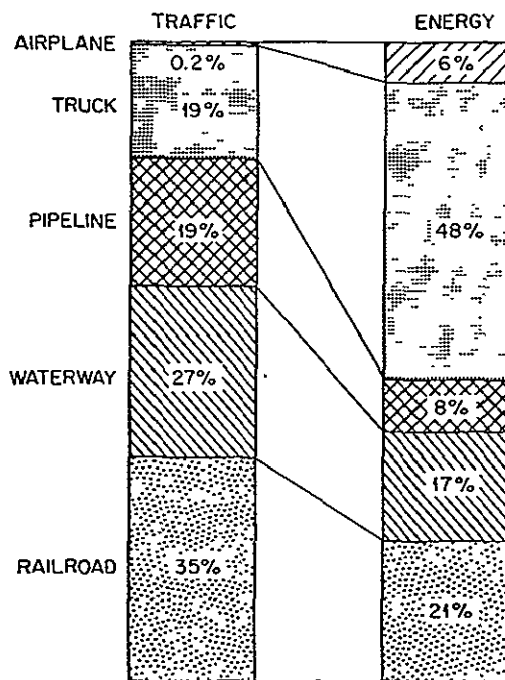


FIGURE 6.1.2-1. 1970 INTER-CITY FREIGHT TRAFFIC AND ENERGY [Hirst-73]

Overall, freight traffic EI declined during the decades 1950-1970, due to the rail transition from coal (steam) to oil (diesel). But this was a one-time gain and the overall EI can be expected to rise if freight traffic continues to shift to modes with higher (and growing) EI's.

Figure 6.1.2-1 shows the 1970 intercity freight traffic and energy distributions. The higher EI's of airplanes and trucks are reflected in the disproportionately high energy consumption compared to the amount of freight moved.

## 6.2 TOTAL ENERGY USE IN TRANSPORTATION

The foregoing discussion of energy intensiveness provides a background for understanding energy usage in transportation. Mutch has developed data showing energy consumption by modes for total passenger and total freight traffic for 1971. [Mutch-73] This data is displayed in Figure 6.2-1. The distribution of energy and traffic displayed in this figure is consistent with the EI trend developed by Hirst.

The total energy consumption in the transportation sector has shown a continuous growth. Figure 6.2-2 displays this growth in consumption. An increasing population, increasing travel per capita, and a shift to more energy intensive modes have all contributed to an energy consumption growth rate of 4-5% per annum since 1955. However, total energy consumption nationally has grown at approximately a parallel pace with transportation thereby accounting for a continuing near constant 25% of the total. As shown in Figure 6.2-2, there has been an increase in the percentage of energy used for passenger transport and a decrease in freight and military transport. Again, this is an indication of the United States' selection of modes with higher EI characteristics.

Transportation has not only historically shifted to modes which are more energy intensive, but the fuel mix has shifted to essentially all petroleum (Figure 6.2-1). Over 95% of transportation energy needs come from petroleum, which indicates how heavily our transportation system relies on this energy source. Capabilities of shifting to other energy sources are extremely limited. Any major shift to alternate fuels will require massive investments and long periods of time. These problems will be discussed subsequently. Figure 6.2-3 and Figure 6.2-4 display the total domestic transportation energy consumption by mode for passenger and freight transportation for the years 1955-1971.

Table 6.2-1 compares modal energy use for 1955 and 1971. [Mitch-73] All modes except marine shipping and railroads show increased energy consumption over the period. Automobiles were the biggest consumers of energy in passenger transportation, while trucks were the major consumer of energy in freight transportation. These two modes are least amenable to substitution of fuel sources under present technology.

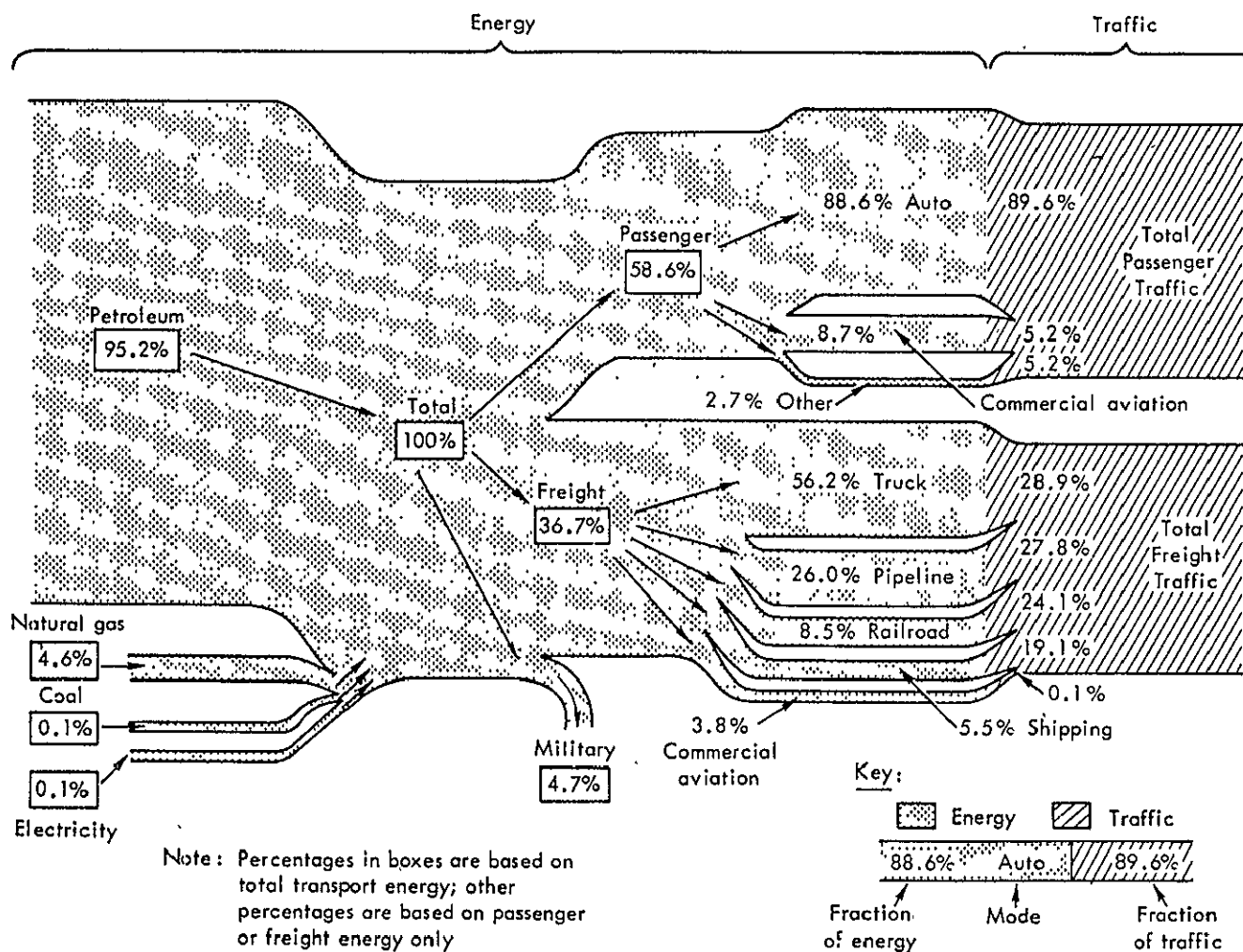


FIGURE 6.2-1. DISTRIBUTION OF TRANSPORTATION ENERGY SOURCES IN 1971, MODAL USES AND MODAL TRAFFIC [Mutch - 73]

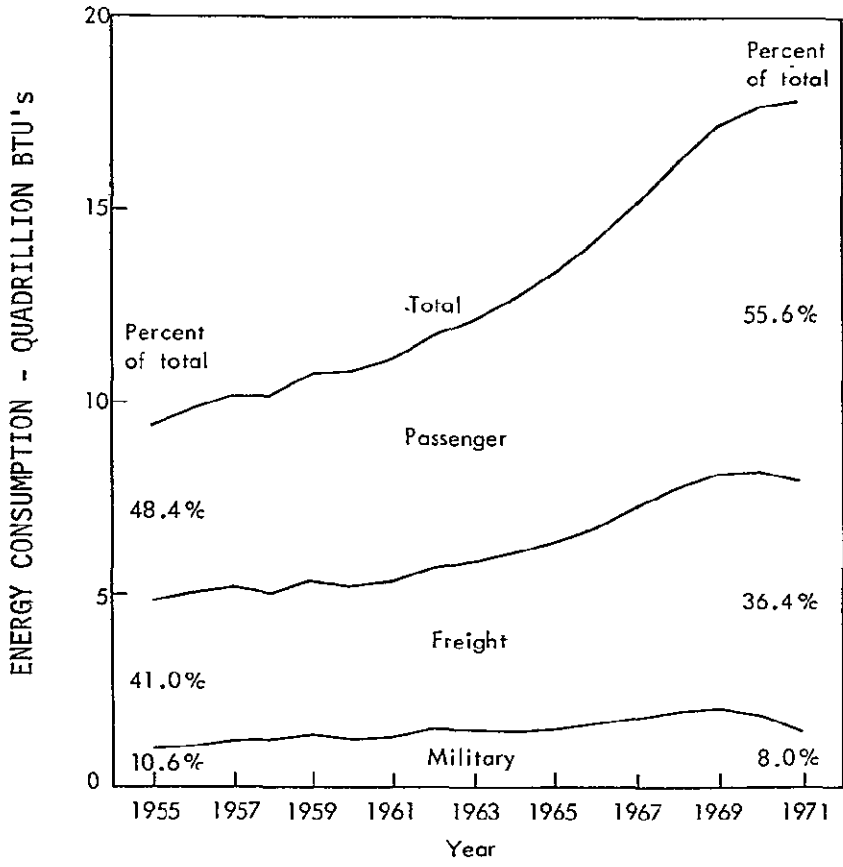


FIGURE 6.2-2. U. S. TRANSPORT ENERGY CONSUMPTION BY END USE, 1955-1971 [Mutch-73]

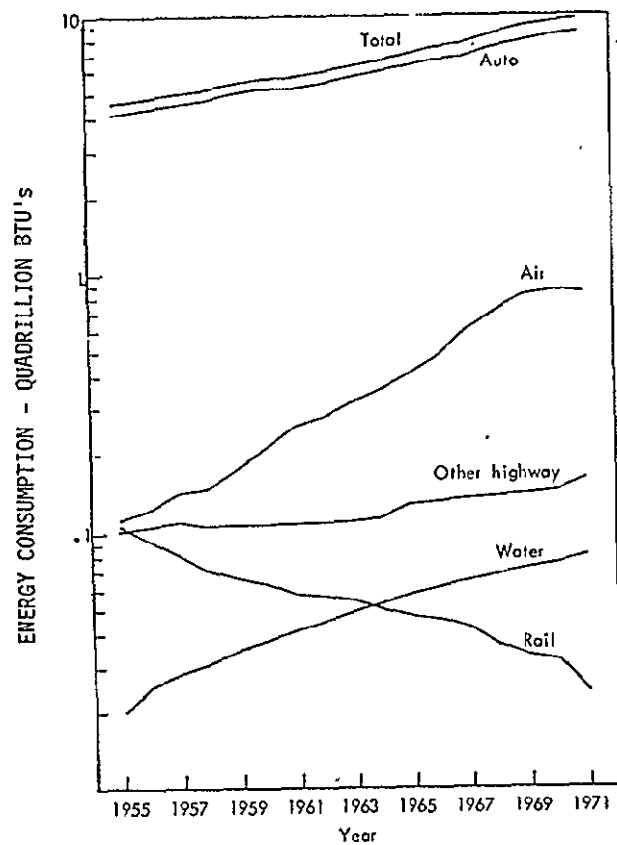


FIGURE 6.2-3. DOMESTIC PASSENGER TRANSPORT ENERGY CONSUMPTION BY MODE, 1955-1971 [Mutch-73]

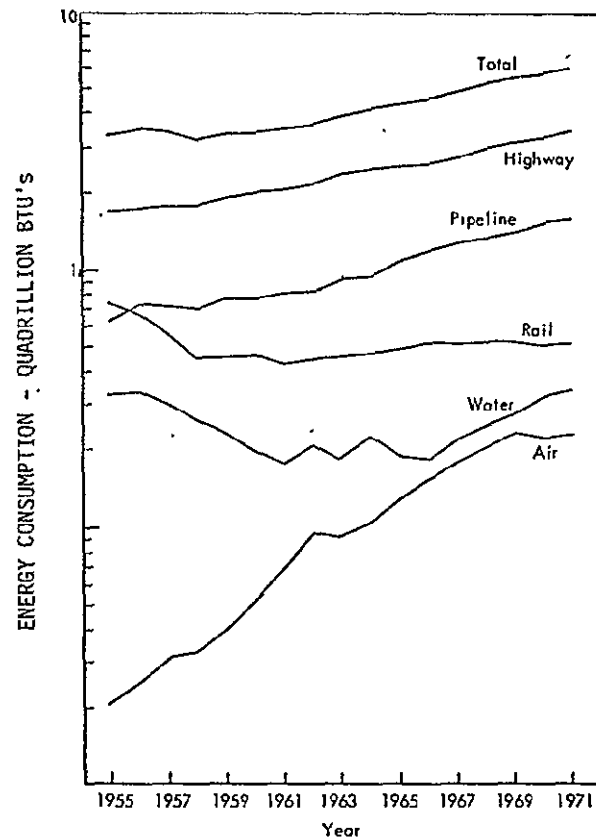


FIGURE 6.2-4. DOMESTIC FREIGHT TRANSPORT ENERGY CONSUMPTION BY MODE, 1955-1971 [Mutch-73]



TABLE 6.2-1  
SUMMARY OF MODAL ENERGY USE, 1955 and 1971 [Mutch-73]

Mode	1955		1971		Energy Consumption	Change In
	Quads	Modal Share (percent)	Quads BTU	Modal Share (percent)	(% Increase or Decrease)	Modal Share Percentage
<u>DOMESTIC</u>						
<u>Passenger</u>						
Automobile	4.19	44.6	8.65	48.2	106	3.6
Air	.11	1.2	.85	4.8	681	3.6
Railroad	.11	1.1	.02	0.1	(77)	(1.0)
Marine	.02	0.2	.08	0.4	305	0.2
Other	.10	1.1	.16	0.9	60	(0.2)
Total	4.53	48.1	9.77	54.4	116	6.3
<u>Freight</u>						
Trucking	1.66	17.7	3.45	19.2	107	1.5
Air	.02	0.2	.23	1.3	1010	1.1
Pipeline	.63	6.7	1.59	8.9	152	2.2
Railroad	.74	7.9	.52	2.9	(30)	(5.0)
Marine shipping	.33	3.5	.34	1.9	5	(1.6)
Total	3.38	36.0	6.13	34.1	81	(1.9)
<u>Military</u>	.57	6.1	.78	4.4	37	(1.7)
Total Domestic	8.48	90.2	16.68	92.9	97	2.7
<u>INTERNATIONAL</u>						
<u>Passenger-Air</u>	.02	0.2	.20	1.1	871	0.9
<u>Freight</u>						
Air	.01	0.1	.13	0.7	1073	0.6
Shipping	.46	4.9	.28	1.5	(40)	(3.4)
Total	.47	5.0	.41	2.2	(14)	(2.6)
<u>Military (total)</u>	.43	4.6	.66	3.4	53	(1.2)
Total International	.92	9.8	1.26	7.1	38	(2.7)
GRAND TOTAL	9.40	100	17.95	100	91	

### 6.3. CONSERVATION STATUS

The transportation sector offers unequalled potentials for conservation. While little potential exists, in the short and middle term, for substitution of alternate fuels, much can be done to reduce demand and increase efficiency of the system. The present conservation status and potential is more understandable if the characteristics of the sector and the legal environment in which it operates is understood.

#### 6.3.1. CONSERVATION BY SUBSTITUTION OF SCARCE RESOURCES.

The basic scarce resource in transportation is petroleum. Substitution of alternate fuels, with the exceptions of methanol, hydrogen, or liquefaction and refining of coal, implies the demise of the internal combustion engine. Research is underway for the development of these fuels for internal combustion fuels. The development of improved battery systems necessary for a practical electrical automobile is also in progress. These alternatives are all practical only in the middle to long term.

#### 6.3.2. CONSERVATION BY REDUCED DEMAND.

Reduced demand offers some potential for energy conservation. But the social and demographic development of this nation has occurred under conditions offering relatively cheap transportation. Since dominant transportation activities occur in conjunction with economic activity, reductions in demand are inextricably linked to levels of economic activity and reductions in one may imply reductions in the other.

#### 6.3.3. CONSERVATION BY IMPROVED EFFICIENCIES

The United States transportation system is characterized by excess capacity. The most damning indication of this excess capacity is perhaps the load factor displayed by the various modes. The cost of this excess capacity is reflected in many forms -- energy waste, excess capital cost, as well as the direct cost to the consumer in terms of high fares and freight rates.

Regulatory policies have undoubtedly had major impact in creating this excess capacity, as well as encouraging its poor utilization. For example, each mode has certain inherent advantages in various types of traffic, and federal regulatory policy has obscured these to a great degree. Barge, rail, and pipeline maintain an inherent cost advantage in the long-haul transportation of bulk commodities. Motor carriers maintain their inherent advantage in smaller point-to-point shipments with shorter distance and speedier deliveries. The Interstate Commerce Commission (ICC) has followed policies in setting up rate structures largely negating these inherent advantages [Fellmeth-70,60]. Consequently, modal selection is not optimized.

A second shortcoming of regulatory policy has been the tacit encouragement of poor utilization of capacity within modes. Examples of this are manifold. Trucks are frequently denied the right to follow the shortest or most efficient route, and backhauls are either not permitted or have severe restrictions. Airline routes suffer from excess capacity and are forced to resort to non-price competition. Examples of this competition appear in the form of gourmet meals and other special services.

An obvious potential for conservation, then, exists in the operation of the transportation system without delving into equipment changes. A thorough evaluation of the possible transportation regulatory policy alternatives and their impacts on modal selection and operation is long past due. Major improvements in energy utilization may well be realized by strictly political action in the regulatory field.

A third obvious potential for conservation is in the efficiency of the hardware used in the system. One only has to look at the percentage of energy used in passenger transportation (Figure 6.2-2) and then look at the portion of this energy devoted to the automobile (Figure 6.2-3) to realize that the automobile is a prime target for energy conservation. And what has been the trend in automobiles? Declining fuel mileage and vehicle utilization have contributed to make the EI of this mode one of the worst of all the modes. Conservation actions which affect the energy consumption of the automobile, as well as those actions which discourage its use, must obviously be of a high priority.

The same sort of argument as made in the previous paragraph concerning the automobile may well be made with the trucking industry in freight movement. The trucking industry is a prime target for conservation actions in the area of hardware. Declining fuel mileage is much in evidence in the last decade, albeit load capacity increases have negated to an extent these mileage losses. Higher powered engines may well be an anachronism under the present lowered speed limits and could be derated with a considerable vehicle mileage gain. [Smart-75]

#### 6.4 GOVERNMENT ACTION STATUS

The Legislative and Executive branches of government have both put forward numerous and conflicting proposals affecting energy conservation in the transportation sector. The present agonies in the establishment of a national energy policy reflect the way our government system functions. The Executive is willing to let price determine conservation action, while Congress would rather rely on regulatory policy.

##### 6.4.1 REGULATORY POLICY AND MODES

Regulatory policies for all modes are presently under review. Lowered speed limits are the most visible policy change, but other changes, such as revision of ICC rate-making procedures are also being considered. The

rationalization of transportation rates to reflect modal advantages has broad support. Proposals to de-regulate large segments of the transportation industry are being considered. These changes in regulatory policy are aimed primarily at modal selection optimization and utilization of equipment.

#### 6.4.2 REGULATORY POLICY AND HARDWARE

The Congress is considering (at the time of this writing) a number of proposals legislating minimum mileage performance standards for new cars and trucks. Typical of this legislation is Senate Bill 1883, which would subject a manufacturer to heavy penalties for failing to meet performance standards. It is noteworthy that most proposed legislation is aimed at achieving a specific performance and not prescriptive in the method by which these goals are achieved.

#### 6.5 SELECTED CONSERVATION ACTIONS

In the remainder of this chapter, the discussion centers about actions capable of achieving energy conservation in this sector. An attempt has been made to document the methodology that was used in identifying and analyzing these actions.

The transportation task group stated its goal as the identification of a set of energy conservation measures which merit consideration in carrying out a public policy of energy conservation. These actions are proposed within the general constraint of achieving a long-range goal of a more effective and efficient transportation system to serve this country's needs. Consideration of their social, political, environmental, and economic impacts was integral to this analysis.

A data base was established in order to evaluate present status and the broad categories in which energy conservation could be achieved were identified. These categories have been identified as improved system efficiency, substitution for scarce resources, and curtailment of end use. Within each of these, sub-categories were established, and specific actions within the sub-categories were identified. Table 6.5-1 lists the principal means of energy conservation and their sub-categories.

The number of specific actions that are possible in each category is quite large. The ones which were addressed were identified in one of two ways. A list of some 800 proposed energy conservation measures was obtained from the FEA. Those that pertained to the transportation sector were extracted. This list was extended by adding those actions which had been uncovered in the literature. The complete list of some 200 actions is shown in Appendix F.3. This list was culled in three different ways; these methods appear in the Appendix on Transportation. The number of specific actions which have been examined in more detail is about 35. Note that most of these actions are very specific.

TABLE 6.5-1  
CLASSIFICATION OF ENERGY CONSERVATION MEASURES IN  
THE TRANSPORTATION SECTOR

- 
- I. Improve System Efficiency
    - A. System Operation Improvements in Efficiency
    - B. Technological Improvements in Efficiency
  - II. Substitution for Scarce Energy Resources
    - A. Electrification of Particular Modes
    - B. Alternate Fuels
    - C. Use of Man Power
    - D. Recycle Transportation Products
  - III. Curtailment of End Use
    - A. Managed Population Growth Rate
    - B. Education of Citizenry
    - C. Alternatives to Personal Transportation
    - D. Improved Urban Planning
    - E. Reduced Travel Incentives
-

In narrowing the original list to this final set, three aspects of the general problem emerged which are so important that these will be briefly discussed before further examination of the specific actions. These three aspects are:

The desirability of producing a scenario for the future

Actions for energy conservation versus implementation of these actions

Regulatory policy as a means for implementation

A number of the actions, originally generated, seemed to be recommendations for improvement of the transportation system, and not necessarily steps toward energy conservation. Yet, the apparent goal of these actions was a more effective transportation system and one that could be achieved only over a long period of time, say 15 to 25 years. Discussion of this group of actions brought out the concept that some long range goals need to be specified. Actions to be taken in the short range, or mid-term, or those initiated now must be consistent with the long-range objective. Presently, the various modes seem to function almost independently of, or in conflict with each other. Increasingly, the trend has been to use the more energy intensive modes. (See Figure 6.1-1, 6.1-2) Furthermore, as shown in Appendix F.6, our transportation energy needs are on a collision course with the ability of our domestic oil companies to produce enough fuel to supply this Sector.

Accordingly, a view toward the year 2000 shows the need for dramatic shifts of transport to the inherently more efficient modes, for improvement in efficiency of each type of transportation, and for changes in lifestyle marked by some reduction in passenger transport, as well as freight movement. Some reduction in passenger transport may occur through the use of telecommunications technology, as it does provide a trade-off between moving people and moving information. (Appendix F.5 presents a brief elaboration of this futuristic possibility.)

It appears that a more integrated transport system within all carriers is needed. This integration might be marked by the location and construction of transport centers. At these focal points, an appropriate interface between land, water and air transport could be available. Thus, direct links could be established between the carriers, and between these transportation centers and urban centers.

A possibility of increased separation between passenger and freight modes may exist, and the development of separate transport centers for each is desirable. To illustrate this group's view, consider only the passenger portion of the sector. Present-day airport facilities may represent Phase 1 of the proposed integrated transport system. High speed rail service emanating from these centers, by-passing smaller towns, and operating over a right-of-way separate from that of present rail systems is envisioned. Furthermore, intercity bus capability would be an important ingredient to the centers, as well as computerized informational systems available to the public. It seems evident that transportation companies -- not merely carriers operating a single mode -- would evolve.

These centers could be equipped to provide efficient service directly into urban areas, or possibly to smaller, connecting centers, from which either additional mass transport systems, or personal carriers could be used to reach an ultimate destination. Finally, an implied feature is that the centers would provide rental services to the public incorporating efficient, low-cost vehicles for travel to the final destination.

The intent of the last few paragraphs was to illustrate the pressing need for an integrated transport service that would more adequately serve the needs of each segment of the public. If this becomes an overriding goal, funding of these enormous projects must come from the public through the government, much as the funding for all interstate highway development has occurred.

The second aspect that became evident as the list of specific actions was studied, was the common practice of linking the specific energy conservation action with the implementation of that action. Yet, in many cases there may be a multitude of methods to carry out the implementation. Primarily, the specific actions have been addressed. In fact, once specific actions have been selected, then systems analysis studies should be conducted to examine the methods of implementation. While implementation methods have not been adequately addressed in this document, there is a general category of these methods that must be discussed at this point. This subject is that of regulation at all levels of government.

#### 6.5.1 REGULATION

Regulation may be accomplished by two methods: (1) changes in policy of present regulatory and administrative agencies, and (2) legislative action. The framework for regulation of the transportation industry already exists in the form of regulatory agencies at all levels of government. Also, legislation, impacting all aspects of the transportation sector, is presently before Congress. The thrust of regulation by the regulatory agencies is in the proposed operation of transportation industry, while legislation affects primarily the system hardware and the distribution and costs of the fuels to run the system.

##### 6.5.1.1 ADMINISTRATIVE REGULATION AND THE TRANSPORTATION INDUSTRY

Regulation by the various agencies has at various times been promotional, protective, or restrictive. Regulation has never had as a goal the overall efficiency of the modes or the integration of transportation modes into an efficient transportation system. The present regulatory structure has been slow to adopt policies which would encourage energy conservation. [Fellmeth-70] Regulation will always provide a mixture of constraints and incentives in all aspects of the transportation field and the extent to which regulation promotes or thwarts energy conservation will change over time. But the important point is that regulation offers an excellent prospect for implementing energy saving innovations.

#### 6.5.1.2 LEGISLATIVE REGULATION AND TRANSPORTATIONS LEGISLATION

Standards for performance of vehicles offer a major energy conservation opportunity. Legislation affecting the price of fuel will be complementary to standards of performance. The present impasse over oil price deregulation is an unusual case where by no action at all, existing legislation will lead to curtailment of use by market forces. Legislation can basically attack the performance of the system hardware and the usage of the hardware by energy costs.

#### 6.5.2 ENERGY CONSERVATION ACTIONS

In considering the entire list of actions generated, it was recognized that it would be impossible to consider every action in detail, in the time available. An effort was made to select those actions which either were being proposed by others as conservation measures, or those that the group perceived to have potential for implementation. The initial listing is not all inclusive; certainly, the final list of actions is not complete. Obviously, other important actions could have been included.

A listing of the specific actions considered in detail is shown in Table 6.5.2-1. Each of these has been studied with respect to energy reduction potential and requirements, and the individual results, are in Appendix F.3.

Examples of these actions and results are shown in Table 6.5.2-2. In compiling this table, judgment and previously published reports have been used to provide estimates of energy reduction potential and the implementation requirements. In many cases, estimates were not available, either due to lack of time or insufficient information. Upon completion of this section of the study, the transportation group further attempted to evaluate the various impacts of these actions, and discussion of these methods is shown in the next section.

#### 6.5.3 ASSESSMENT OF ACTIONS

Thirty-four actions were chosen on the basis of the preliminary filtering process and these are displayed in Table 6.5.2-1. It was the task group's objective to be able to demonstrate (1) a methodological approach to arrive at logical and consistent conservation action packages and (2) to be able to recommend a viable and supportable specific set of actions. Even though time did not permit complete development of the approach illustrated, it appears to have merit. As to the sets of conservation actions which sifted through our assessment process, it is evident that much greater impact assessment effort is needed to be assured that a viable set of actions has been selected. Discussion here will be confined to a brief illustration of the assessment methodology which was used. An elaboration of this, plus a full set of all tables, is contained in Appendix F.4.



TABLE 6.5.2-1 . ENERGY CONSERVATION ACTIONS IN THE TRANSPORTATION SECTOR

<u>I. Improve System Efficiency</u>	
A. System Operations Improvement	B. Technological Improvement
1. Use modes that are inherently more efficient	8. Use lighter weight autos
2. Shift from truck to rail	9. Design for prolonged life
3. Form carpools	10. Develop stratified charge engine
4. Shift passenger traffic from auto to bus and/or rail	11. Investigate other improved engine designs Stirling cycles, gas turbines, rotary engines, Rankine cycle engines
5. Use auto-train and/or railroad and airport auto rental	12. Improve transmissions Better matched to engines Elimination or improvement of automatic transmissions, or with lock up
6. Optimize air routes by eliminating short hauls, increasing load factors, and reducing cruise speed	13. Explore hydrid systems (flywheel, hydraulic battery storage, etc.)
7. 55 mph speed limit	14. Improve tires (radials)
	15. Study aerodynamic improvements
<u>II. Substitution for Scarce Energy Resources</u>	
A. Electrification of Particular Modes	B. Alternate Fuels
16. Electric automobiles	18. Hydrogen
17. Electrification of railroads and urban buses—	19. Other fuels (methanol, liquified methane, ammonia, etc.)
C. Use of Manpower	D. Recycle Transportation Products
20. Promote a bikeway program	22. Reprocess wornout transportation vehicles
21. Walk, rather than drive	23. Recycle lubrication oils
<u>III. Curtailment of End Use</u>	
A. Managed Population Growth Rate	B. Education of All Citizens
24. Promote planned parenthood	26. Obtain support of groups like League of Women Voters
25. Reduce immigration into this country	27. Support public education programs
	28. Obtain support of corporations to provide employee incentives
C. Alternatives to Personal Transportation	D. Improved Urban Planning
29. Use telecommunications to eliminate travel	31. Develop and publicize local recreation and entertainment possibilities
30. Provide more delivery services of purchased goods	32. Locate shopping centers within walking distance
	33. Ban parking in downtown areas
E. 34. Reduced travel incentives	

TABLE 6.5.2-2 ACTIONS TO CONSERVE ENERGY IN THE TRANSPORTATION  
SECTOR: ENERGY REDUCTION POTENTIAL AND REQUIREMENTS

ACTION GROUP	ACTION	TIME TO IMPLEMENT	ENERGY REDUCTION POTENTIAL	IMPLEMENTATION REQUIREMENTS		
				COST	MANPOWER	MATERIALS
I. Improve System						
A. System Operations improvement	1	M - L	L	L	L	L
	2	N - M	M	S	S	S
	3	N	L	S	S	S
	4	N - M	M	M	M	M
	5	M	M	M	S	M
	6	N - M	M	S	S	S
	7	N	L	S	S	S
B. Technological Improvement	8	N	L	S	S	S
	9	N - M	S	S	S	S
	10	N	M	S	S	S
	11	N - M	M	M	S	S
	12	N	S	S	S	S
	13	M	M	M	S	S
	14	N	M	S	S	S
	15	N	S	S	S	S
II. Substitution for Scarce Energy Resources	16	N - L	L	M	M	M
A. Electrification of Part. Modes	17	M - L	M	M	M	M

The assessment methodology centers around three separate phases:\*

Impact assessment

Decision making

Cross-evaluation

Institutional, socio-economic and environmental impacts were examined for the thirty-four actions. Each of the 34 actions was addressed by the members of the task group together, discussed relative to the various impacts and given a consensus ranking score. Consider the formation of carpools, Action I-A.3, shown in the assessment matrix for environmental impacts, Table 6.5.3-1. It was felt that carpools would tend to reduce the number of automobiles traveling, hence, it has a favorable impact on air pollution. So, it received a (+). Similarly, it was felt that carpooling would reduce noise pollution and help to relieve traffic congestion . . . +'s were assigned. Carpooling was judged to have only a small effect on land use patterns, hence it received an SE. Definitions of all impacts are given in Appendix F.4.

Once the impact matrices were complete, a numerical ranking score was devised to depict the effect of each action in each of the impact areas and the conservation potential-requirements matrix. A rank score on the basis of 0 to 10 was established for each action based on these four broad criteria. These rank scores are recorded in the Decision Matrix, Table 6.5.3-2, in the upper left hand corners of the cells. The transportation task group chose to weight the four criteria as indicated in the row labeled "Weighting Factor". Each ranking score was multiplied by the criterion weighting factor to produce the number in the lower right of each cell. These "weighted ranked" scores were added to produce the total score column. By choosing a cutoff score one can filter the list and reduce its size. Consider, for illustrative purposes, all actions with scores greater than 6.4, the mean of all 34 weighted total scores. There are 20 actions which remain. Screening these 20 actions further for those which appear to be capable of being clearly implemented in the near term 1975-1985, eleven actions -- 3, 7, 8, 10, 14, 15, 26, 27, 28, 33, 34 -- are identified and appear to be desirable.

Consider the following questions. Do these actions represent a consistent set? Is it possible to attempt to implement all of these simultaneously, or is it possible that some of these actions, if implemented simultaneously, would interfere with each other? Another question that could be asked is, "Are there groups of these actions that might naturally go together in a reinforcing way? Could we have dropped unwittingly some actions that should be retained with the eleven near term actions simply because they might be synergistic in their interaction?"

---

\*The following documents were helpful in arriving at this methodology: [Coates-74], [Heydinger-74], [Hill-70], [Krzyczkowski-75], and [Voorhees-74].

TABLE 6.5.3-1 ACTIONS TO CONSERVE ENERGY  
IN THE TRANSPORTATION SECTOR: ENVIRONMENTAL EFFECTS

Action Group	Action	Air Pollution	Noise Pollution	Traffic Congestion	Land Use Patterns
I-A	1	+	+	+	LE
	2	+	+	+	NE
	3	+	+	+	SE
	4	+	+	+	SE
	5	+	+	+	SE
	6	0	+	-	NE
	7	+	+	0	NE
I-B	8	+	+	+	NE
	9	+	0	0	SE
	10	+	0	0	NE
	11	+	0	0	NE
	12	+	0	0	NE
	13	+	+	0	NE
	14	+	-	0	NE
	15	+	+	0	NE
II-A	16	+	+	0	SE
	17	+	+	+	SF

TABLE 6.5.3-1 (Con't) ACTIONS TO CONSERVE ENERGY  
IN THE TRANSPORTATION SECTION: ENVIRONMENTAL EFFECTS

Action Group	Action	Air Pollution	Noise Pollution	Traffic Congestion	Land Use Patterns
II-B	18	+	0	0	SE
	19	+	0	0	NE
II-C	20	+	+	+	SE
	21	+	+	+	SE
II-D	22	0	0	0	NE
	23	0	0	0	NE
III-A	24	+	+	+	LE
	25	+	+	+	SE
III-B	26	+	+	+	NE
	27	+	+	+	NE
	28	+	+	+	SE
III-C	29	+	+	+	LE
	30	+	+	+	SE
III-D	31	+	+	+	SE
	32	+	+	+	LE
	33	+	+	+	SE
III-E	34	+	+	+	NE

TABLE 6.5.3-2. DECISION MATRIX

ACTIONS	CONSERVATION POTENTIAL	INSTITUTIONAL IMPACTS	SOCIO- ECONOMIC IMPACTS	ENVIRON- MENTAL IMPACTS	TOTAL WEIGHTED SCORE
WEIGHTING FACTOR	0.4	0.1	0.3	0.2	
1	5 / 2.0	4 / .4	8 / 2.4	8 / 1.6	6.4
2	8 / 3.2	7 / .7	5 / 1.5	4 / .8	6.2
3	10 / 4.0	7 / .7	7 / 2.1	6 / 1.2	8.0
4	6 / 2.4	5 / .5	7 / 2.1	6 / 1.2	6.2
5	6 / 2.4	6 / .6	9 / 2.7	4 / .8	6.5
6	8 / 3.2	6 / .6	5 / 1.5	3 / .6	5.9
7	9 / 3.6	5 / .5	8 / 2.4	5 / 1.0	7.5
8	10 / 4.0	8 / .8	3 / .9	6 / 1.2	6.9
9	7 / 2.8	7 / .7	5 / 1.5	2 / .4	5.4
10	8 / 3.2	10 / 1.0	6 / 1.8	5 / 1.0	7.0
11	7 / 2.8	10 / 1.0	6 / 1.8	4 / .8	6.4
12	7 / 2.8	10 / 1.0	6 / 1.8	3 / .6	6.2
13	8 / 3.2	9 / .9	6 / 1.8	7 / 1.4	7.3
14	8 / 3.2	10 / 1.0	7 / 2.1	3 / .6	6.9
15	7 / 2.8	10 / 1.0	6 / 1.8	4 / .8	6.4
16	7 / 2.8	3 / .3	5 / 1.5	6 / 1.2	5.8
17	5 / 2.0	4 / .4	4 / 1.2	6 / 1.2	4.8
18	4 / 1.6	1 / .1	5 / 1.5	4 / .8	4.0
19	7 / 2.8	3 / .3	5 / 1.5	3 / .6	5.2
20	7 / 2.8	10 / 1.0	5 / 1.5	5 / 1.0	6.3
21	7 / 2.8	8 / .8	4 / 1.2	4 / .8	5.6
22	7 / 2.8	6 / .6	6 / 1.8	1 / .2	5.4
23	7 / 2.8	6 / .6	5 / 1.5	1 / .2	5.1
24	9 / 3.6	5 / .5	4 / 1.2	6 / 1.2	6.5
25	7 / 2.8	7 / .7	6 / 1.8	4 / .8	6.1
26	8 / 3.2	10 / 1.0	7 / 2.1	6 / 1.2	7.5
27	8 / 3.2	6 / .6	7 / 2.1	6 / 1.2	7.1
28	7 / 2.8	8 / .8	8 / 2.4	6 / 1.2	7.2
29	8 / 3.2	2 / .2	7 / 2.1	8 / 1.6	7.1
30	7 / 2.8	10 / 1.0	8 / 2.4	4 / .8	7.0
31	6 / 2.4	9 / .9	7 / 2.1	4 / .8	6.2
32	6 / 2.4	9 / .9	8 / 2.4	5 / 1.0	6.7
33	8 / 3.2	6 / .6	6 / 1.8	7 / 1.4	7.6
34	9 / 3.6	3 / .3	7 / 2.1	7 / 1.4	7.4

## RANKING SCALE FOR THE ABOVE FOUR CRITERIA:

1. CONSERVATION POTENTIAL: 0 = LOW POTENTIAL; 10 = HIGH POTENTIAL.
2. INSTITUTIONAL IMPACTS: 0 = GREAT IMPLEMENTATION AND INSTITUTIONAL DIFFICULTIES; 10 = FEW DIFFICULTIES AND PROBLEMS.
3. SOCIOECONOMIC IMPACTS: 0 = UNDESIRABLE OUTCOME OR IMPACTS; 10 = DESIRABLE IMPACTS.
4. ENVIRONMENTAL IMPACTS: 0 = UNDESIRABLE CONSEQUENCES; 10 = DESIRABLE CONSEQUENCES.

ORIGINAL PAGE IS  
OF POOR QUALITY

In order to gain some perspective on these kinds of questions the Cross Evaluation Matrix, Table 6.5.3-3, was developed. All 34 actions were compared with each other in terms of the four categories displayed in the Table. The transportation task group completed the cross evaluation matrix as a group with discussion and debate until a consensus was reached. To illustrate how the cross evaluation matrix might be used to further refine and analyze a set of actions, let us form a new cross evaluation matrix, a subset of the eleven near term actions filtered from the decision matrix Table 6.5.3-2.

These eleven actions are listed below and a reduced cross evaluation matrix is presented in Table 6.5.3-4.

<u>Action No.</u>	
3	Form carpools
7	55 MPH speed limit
8	Use lighter weight autos
10	Stratified charge engine
14	Improved tires
15	Aerodynamic improvements
26	Obtain support of League of Woman voters
27	Support public education programs
28	Obtain support of corporations to provide employee incentives
33	Ban parking in downtown areas
34	Reduce travel incentives

A study of Table 6.5.3-4 indicates that most of these actions are either complimentary or independent and could be introduced simultaneously without producing adverse interactions relative to energy conservation. Five cells, however, have (T's) indicating a possible trade-off relationship. Actions 8, 10, 14 and 15 all fall into the category "Technological Improvement" which seeks to improve the technical efficiency of engines and automobiles. Action 34 is a broad set which could be imposed to reduce travel incentives or conversely to create travel disincentives. Fuel price increase as a policy to reduce travel would be compromised by substantial technological efficiency improvements which might have the effect of encouraging more travel. Action 7 (55 MPH speed limit) renders less useful action 15 (aerodynamic improvements). If a 55 MPH speed limit

TABLE 6.5.3-3. CROSS EVALUATION MATRIX

		CONSERVATION ACTIONS																																		
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	
I-A	1	C	C	C	C	C	C	T	I	T	T	T	T	T	T	T	C	U	U	C	C	I	I	T	T	C	C	C	U	T	I	I	C	U		
	2		I	I	I	U	C	I	I	T	T	T	T	T	T	I	C	U	U	I	I	I	I	I	I	C	C	I	I	T	I	I	I	I		
	3			T	I	I	I	U	I	I	I	I	I	I	I	I	T	I	I	U	I	I	I	I	I	C	C	C	I	I	I	U	C	C		
	4				C	C	C	U	I	T	T	T	T	T	T	T	C	U	U	I	I	I	I	I	I	C	C	C	I	C	I	T	C	C		
	5					I	C	U	I	I	I	I	I	I	I	I	C	C	U	U	I	I	I	I	I	C	C	C	T	I	I	I	I	T		
	6						I	I	I	I	I	I	I	I	I	I	I	C	C	I	I	I	I	I	I	C	C	I	T	I	I	I	I	T		
	7							C	I	C	C	I	C	I	T	C	I	I	I	I	I	I	I	I	I	C	C	C	C	I	I	I	I	I		
I-B	8								C	C	C	C	C	C	C	C	C	I	U	U	I	I	C	I	I	I	C	C	I	I	T	I	T	T	T	
	9									C	C	C	C	C	C	C	C	I	U	U	I	I	C	I	I	I	C	C	I	T	T	I	I	T	T	
	10											I	I	I	I	I	T	T	I	I	I	I	I	I	I	C	C	I	T	I	I	I	I	T		
	11												I	I	I	I	I	T	T	I	I	I	I	I	I	I	C	C	I	T	I	I	I	I	T	
	12													C	I	I	T	T	I	I	I	I	I	I	I	I	C	C	I	T	I	I	I	I	T	
	13															I	T	T	T	I	I	I	I	I	I	I	C	C	I	T	C	I	I	I	T	
	14																I	I	T	I	I	I	I	I	I	I	C	C	I	T	C	I	I	I	T	
II-A	15																I	I	I	I	I	I	I	I	I	C	C	I	T	I	I	I	I	T		
	16																	T	T	T	I	I	I	I	I	C	C	I	T	C	I	I	I	T		
	17																		T	T	I	I	I	I	I	I	C	C	T	I	I	I	C	T		
II-B	18																			T	I	I	I	I	I	I	C	C	I	T	C	I	I	T	T	
	19																				I	I	I	I	I	I	C	C	I	T	C	I	I	T	T	
II-C	20																					I	I	I	I	I	C	C	C	C	C	C	C	C	C	
	21																						I	I	I	I	C	C	C	C	C	C	C	C	C	
II-D	22																							I	I	I	C	C	I	I	I	I	I	I	I	
	23																								I	I	C	C	I	I	I	I	I	I	I	
III-A	24																									I	C	C	C	I	I	I	I	I	I	
	25																										C	C	I	I	I	I	I	I	I	
III-B	26																											C	C	C	C	C	C	C	C	C
	27																											C	C	C	C	C	C	C	C	C
	28																												C	C	C	C	C	C	C	C
III-C	29																												C	C	U	C	C	C	C	C
	30																													C	C	U	C	C	C	C
III-D	31																														C	C	U	C	C	C
	32																															C	C	U	C	C
III-E	33																																			C
	34																																			C

**C -- TWO ACTIONS ARE DIRECTLY COMPLEMENTARY OR REINFORCING.**

**T --- TWO ACTIONS ARE TRADEOFF, CONFLICTING, BOTH ATTEMPTED SIMULTANEOUSLY MIGHT TEND TO BE COUNTER PRODUCTIVE.**

1 -- MUTUALLY EXCLUSIVE ACTIONS EACH CAN BE ACCOMPLISHED INDEPENDENTLY OF THE OTHER.

U — ACTION RELATIONS UNCERTAIN, COULD BE (C) OR (T). IDENTIFIES AREAS OF POLICY CONFLICT.



TABLE 6.5.3-4

REDUCED CROSS EVALUATION MATRIX  
FOR  
A SUBSET OF NEAR TERM ACTIONS  
WITH ABOVE AVERAGE RANKING SCORES

[illegible]

were to become a rigidly enforced law, it might not pay to exert much effort to streamline cars and trucks, since drag resistance is a function of high speeds.

Looking at the full cross evaluation Table 6.5.3-3, and assuming that action 33 (ban parking in downtown areas) was to be implemented, an examination of column 33 indicates that actions 1 and 4 should probably be seriously considered in addition to action 33. Ban of parking in downtown areas would need to be accompanied by improvements in mass urban transport so that people could shift to more efficient modes. Thus, the results falling out of the sifting from the decision matrix, Table 6.5.3-2, might have to be modified in terms of insights gained from study and analysis of the cross evaluation matrix.

All judgements made during the foregoing sifting process, stepping from the impact matrices to the decision matrix to the cross evaluation matrix, have been made by the four members of the transportation task force group. These judgements have been made on the basis of limited personal data bases acquired in the early weeks of this systems design project. Therefore, the reader should look upon the results portrayed here as simply an illustration of a method which might be helpful in forming a consistent package of conservation actions. The reader might wish to supply his own rankings for some of the actions illustrated and elaborated upon in Appendix F.4 and work his way through the three step process to compare his results with those presented here.

## CHAPTER 7. ENERGY CONSERVATION AND THE RESIDENTIAL AND COMMERCIAL SECTOR

A detailed analysis of conservation actions relevant to the sector leads one to the conclusion that the potential for savings is great. If the nation is determined to curtail its dependence on oil imports, concerted efforts must be made to achieve this potential. The task will not be easy, however, since many of the actions require significant life style changes that are difficult to accomplish. For example, turning back thermostats at night, reducing lighting, and maintaining proper conditioning of appliances are apparently easy tasks to achieve, but evidence indicates otherwise. Even the retrofitting of homes is hindered by initial costs, although the payback period is short. Also consumption patterns are very unpredictable; families living in nearly identical homes may vary radically in energy demands.

Furthermore, many of the conservation actions that are cited as "instant" solutions to the energy crisis are those with only mid to long term potential. Solar energy is one example; heat pumps is another.

There are ways of accomplishing very significant savings in the residential/commercial sector. Three approaches are viable: adjusting price structure, mandating actions, and educating consumers. Of these three, the first two appear to be the most feasible. But they are not without a price. Higher utility bills adversely affect the poor and the elderly on fixed incomes. Likewise, strict mandatory measures can be quite distasteful. But the effect of alternatives, such as voluntary savings accomplished through education processes, is minimal in a nation without a true conservation ethic. These conclusions were based on a detailed assessment of five conservation actions selected by the task group after an initial filtering process. The procedure also allowed a display of the systems approach as a viable methodology in assessing conservation actions. Application of the approach led to a set of recommendations that the task group considers to merit further assessment.

## 7.1 INTRODUCTION

This section of the report is concerned specifically with the efforts to conserve energy in the residential/commercial sectors. For the purpose of the study, the residential and commercial sectors are examined separately. In order to develop a residential and commercial inventory and unit demand data, the group relied on Project Independence data. [PI-74-5]

The objectives of the residential and commercial task group were as follows:

- Compile and analyze existing data relevant to energy conservation in the residential/commercial sector.

- Identify energy conservation actions particular to the sector and according to the categories: reducing use, increasing efficiency, and substituting for scarce energy resources.

- Filter the actions through a conservation action evaluation matrix in order to obtain a qualitative assessment of the overall feasibility of the various actions in the time frame of 1975-1985.

- Assess the impacts of specific conservation actions. Impacts refer not only to social, political and environmental considerations, but also to requirements (money, supplies, and manpower) that would be needed to implement a specific action.

- Develop and illustrate the methodology used in the above assessment of impacts. The methodology would incorporate the systems approach and serve as a viable tool for other groups involved in the assessment of conservation actions.

In order to achieve the above objectives, three sub-task groups were formed to investigate energy conservation by: (1) reducing consumption, (2) increasing efficiency, and (3) substituting for scarce energy resources. A systems diagram, shown in Appendix G, was developed for each sub-task group objective. The schematic of the overall system diagram for the Residential/Commercial sector is shown in Figure 7.1-1. Each sub-task group proceeded by:

- Compiling existing data relevant to sub-task group

- Identifying conservation actions

- Assessing feasibility of conservation actions using an evaluation matrix

- Assessing the impacts of specific conservation actions utilizing cross-cut groups for input

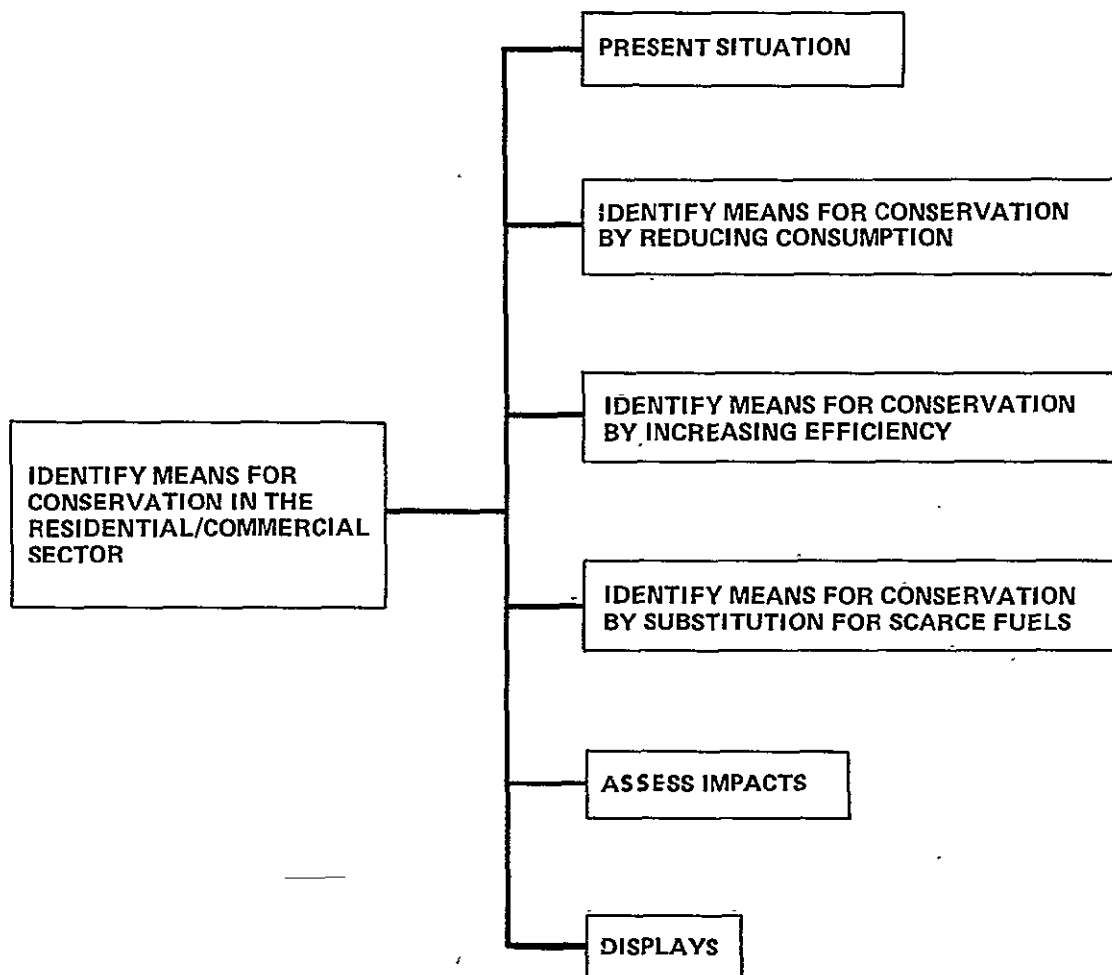


FIGURE 7.1-1

## SCHEMATIC OF RESIDENTIAL/COMMERCIAL TASK GROUP SYSTEMS APPROACH

## 7.2 CONSUMPTION STATUS

In 1970, the Continental United States consumed 15.3 quadrillion BTU's (quads) of energy at point of use (including power plant losses, in the residential and commercial sectors). Of this total 11.4 quads (75%) were consumed in the residential sector and 3.9 quads (25%) in the commercial sector.

Figures 7.2-1 and 7.2-2 show 1970 energy demand by end use and is based on: (1) the assumption that electricity is measured at the point of entry to the building (3,413 BTU/kWh); and (2) the assumption that power plant losses and distribution losses are included in the measurement. The graphs clearly show the extent to which demand is understated using the point of entry assumption. The assumption is appropriate for a demand analysis, however, because it does not raise the issue of power plant fuel or efficiency, which properly belongs in a supply analysis. Two significant conclusions obtained from Figure 7.2-1 are that (1) the residential market, with 75% of the energy demand at point of consumption, is the dominant sector; and (2) the space heating load is dominant in both sectors, with approximately 70% of the total energy used for that purpose. Table 7.2-1 compares residential and commercial consumption by listing the average per-square-foot demand for selected end uses on a national basis. Figure 7.2-3 shows that the four census regions have grossly different fuel consumption patterns. This is a factor which clearly complicates the problem of finding universal solutions to the energy crisis.

## 7.3 CONSERVATION STATUS

The potential for energy conservation in the residential/commercial sector has been studied by several groups.

A National Petroleum Council study [NPC-74-1] identifies the areas that offer the greatest potential for near-term energy savings as measures that deal with: (1) life-styles, (2) upgrading thermal performances, and (3) heating, ventilating and air conditioning systems. In regard to life-styles, the study relates that the potential for energy savings in the residential market by conservation measures which require no investment is extremely large. For example, actions that reduce the use of hot water, internal building temperatures, and water heater temperatures have a total potential savings of nearly 19 percent of the energy consumed by the residential sector in 1972. The potential and maximum assumed achievable levels of savings for various conservation measures are shown in Table 7.3-1. The maximum assumed achievable conservation potential data are subjectively derived based on cost, timing, public compliance and consumer education. Consumer education is certainly considered to be one of the most important

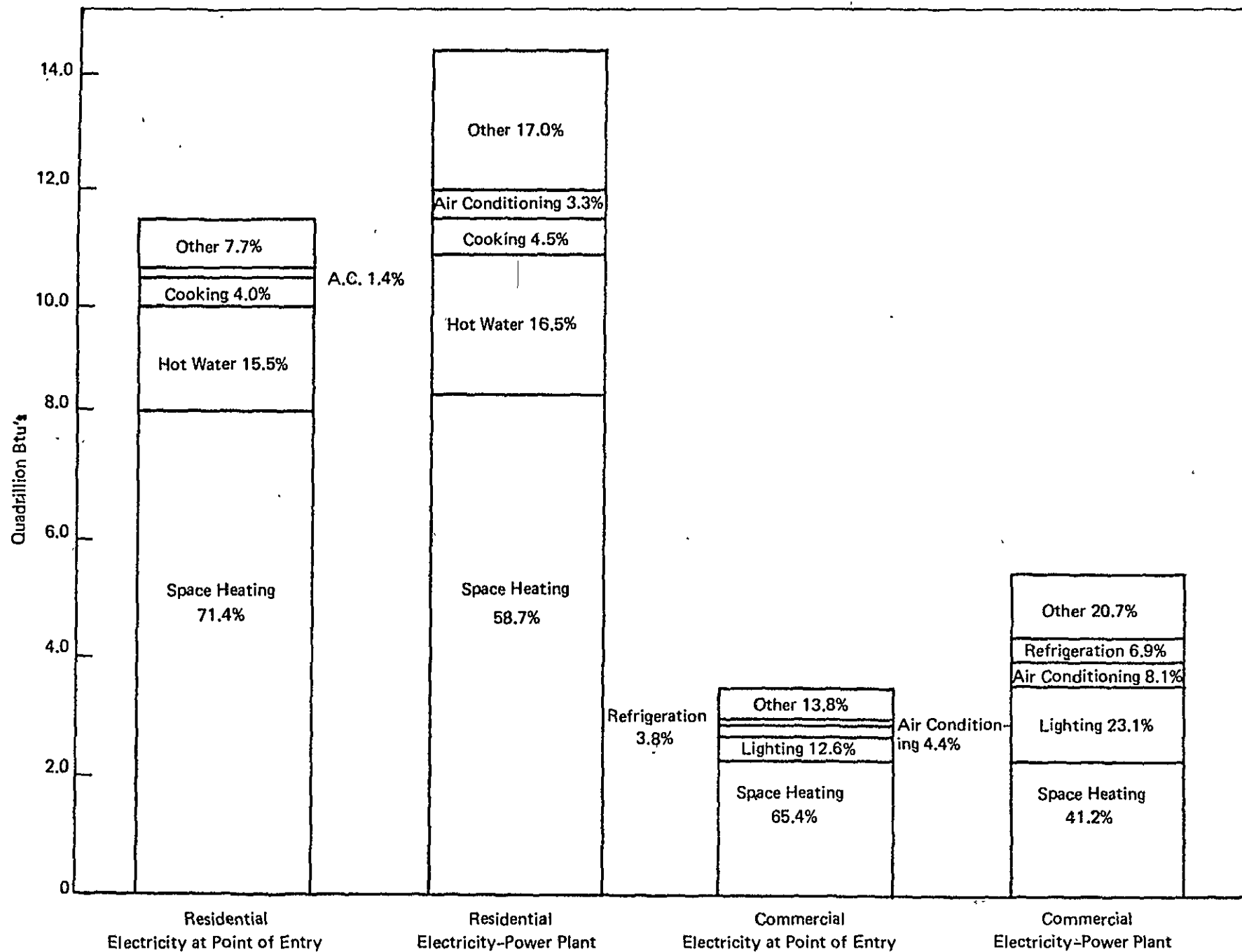


FIGURE 7.2-1. 1970 ENERGY DEMAND BY END USE [PI-74-5, 8]

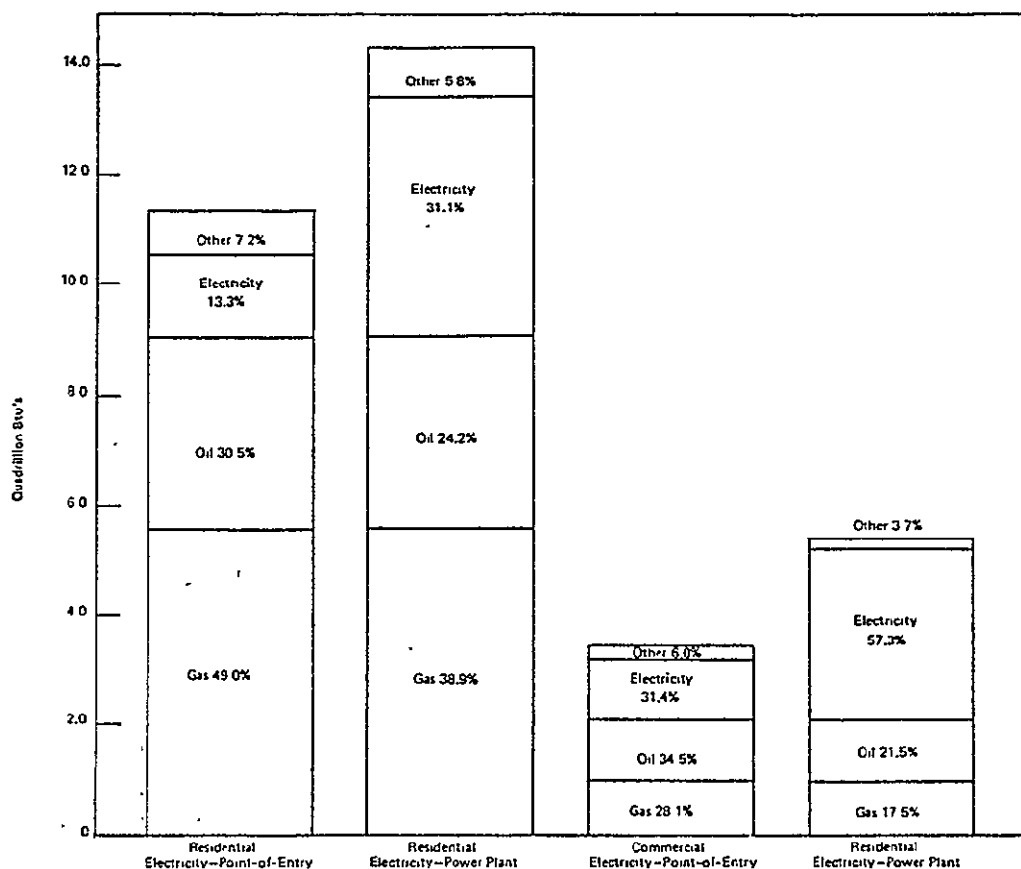


FIGURE 7.2-2. 1970 ENERGY DEMAND BY FUEL TYPE [PI-74-5, 9]

TABLE 7.2-1

ENERGY USAGE COMPARISONS<sup>a</sup>  
 (Residential Versus Commercial) [PI-74-5, 11]

	<u>Residential</u>	<u>Commercial</u>
Million Square Feet	75,600	21,610
Trillion BTU's	11,411	3,375 <sup>a</sup>
BTU/Square Foot	150,900	156,200

BTU/Square Foot  
 By Selected End Use

	<u>Residential</u>	<u>Commercial</u>	<u>Commercial ÷ Residential</u>
Total	150,900	156,200	1.03
Heat	107,800	102,100	0.95
Air Conditioning <sup>b</sup>	10,000	13,400	1.34
Water	23,400	5,000	0.21
Lighting	2,000	19,800	9.87

a. Excludes 510 million BTU's "unallocated."

b. For units which are air conditioned.



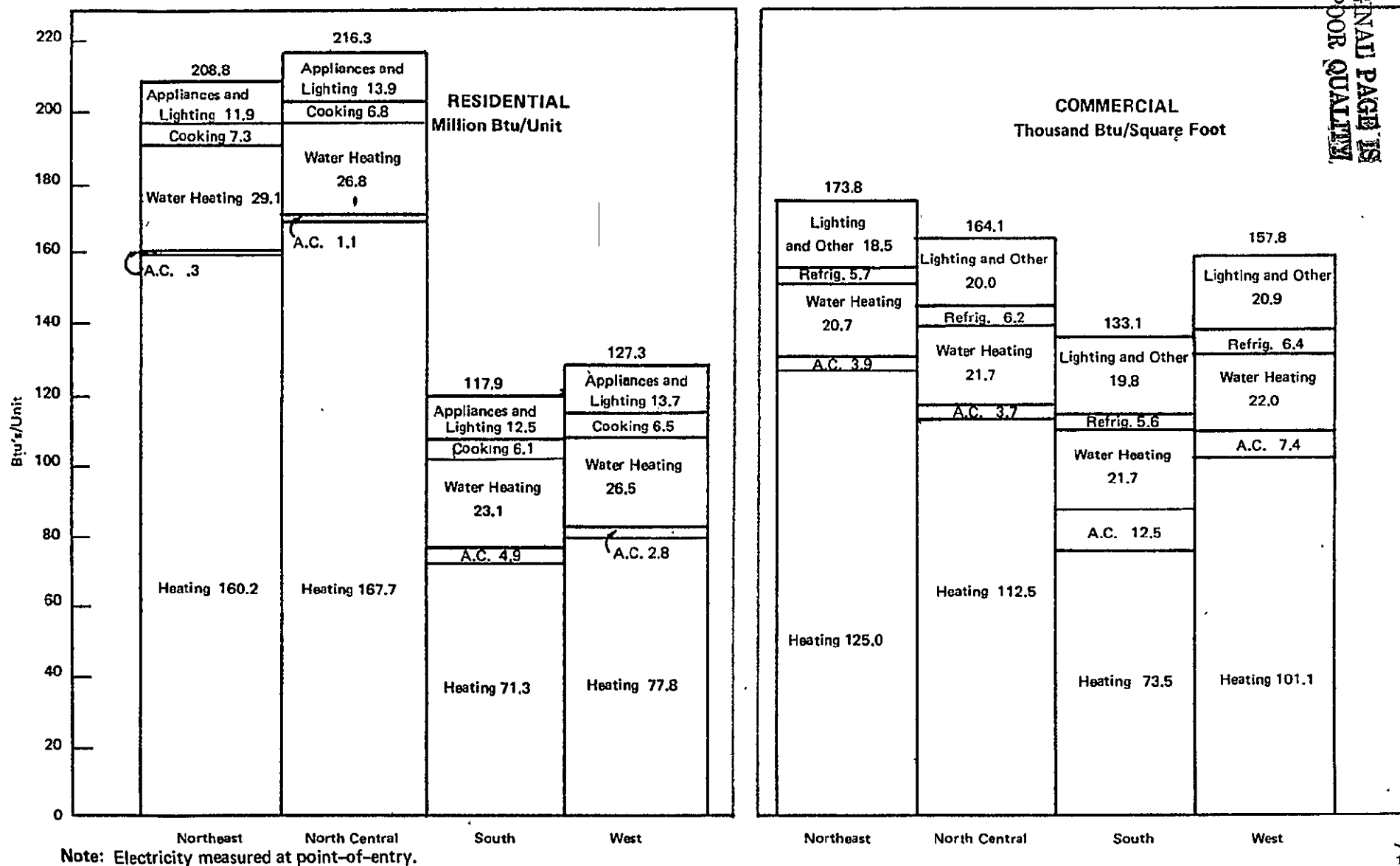


FIGURE 7.2-3. ENERGY DEMAND BY REGION AND END USE PER UNIT [PI-74-1]

TABLE 7.3-1 POTENTIAL ENERGY SAVINGS IN THE RESIDENTIAL SECTOR (QUADRILLION BTU'S)

Modified from  
Ford Report  
[Ford 74-50]

Technical Fix vs. Historical Growth

	1985	2000	
Residential energy use in HG scenario	24	32	
Potential Savings			Conservation Measures
Space heat	1.0 0.1 1.8 --- 0.1	3.1 0.6 3.4 0.3 0.2	Insulation against heat loss More efficient fossil fuel furnaces Heat pumps instead of resistance heat Solar heating Electric igniters instead of pilot lights
Air conditioning	0.6 0.3	0.9 0.6	Improved efficiency Insulation against heat infiltration
Water heat	0.5 0.1 ---	1.2 0.2 0.2	Fossil fuel or solar instead of electric Electric igniters More efficient heaters
Other	0.7	1.0	
Total savings	5.2	11.7	
Residential energy use in TF scenario	19	20	

Note: The residential sector's share of all energy processing losses are included in these numbers.

Modified from National Petroleum Council Report [NPC-74-1,8]

Rank	Life-Style	Savings 1978	
		Total Potential Trillion BTU'S	Maximum Assumed Achievable
1	Set Thermostat Back to 68°F (day)	993	745
3	Set Water Heater Back to 120°F	405	203
7	Set Air Conditioner Thermostat Up to 78°F	97	49
8	Set 8 Hour Thermostat Back to 60°F (night)	463	46
9	Reduce Bathing Water Consumption One-Third	252	25
10	Turn Off Pilots in Gas Furnaces	56	17
	Total	2,266	1,085
	Insulation, Storm Doors and Windows, Caulking		
2	Ceiling Insulation	733	367
4	Weatherstripping and Caulking	325	140
6	Storm Doors and Windows	128	64
	Total	1,186	571
	Heating/Cooling		
5	Furnace Tune-up	662	66
11	Air Conditioner Tune-up	97	13
	Total	759	79
	Grand Total	4,211	1,735

factors in attaining achievable levels in the residential sector. Also, experience indicates that two strong motives for conserving energy are to save money and reduce the prospects of future shortages. In regard to consumer education, then, perhaps the key monetary message to consumers should be the length of the payback period and actual dollar savings resulting from the installation of energy conserving devices. This approach certainly buffers high initial costs -- a deterrent in many instances to implementation.

As in the residential sector, the National Petroleum Council study also analyzed the potential for various conservation actions in the commercial sector. These are listed in Table 7.3-2.

In the Ford Foundation Report [Ford-74], a "Technical Fix" scenario assumes annual energy consumption increasing at an average rate of 1.9 percent per year between now and the year 2000, (from 75 quads in 1973 to 124 quads in 2000). They contend that the energy budget can provide essentially the same level of energy services, and levels of heating and cooling, manufacturing output, etc. as their "Historical Growth" scenario if the nation adopts specific energy saving technologies. Tables 7.3-1 and 7.3-2 list potential savings in the residential/commercial sector. The Ford Report also states that energy conservation in the residential/commercial sector is primarily a function of building design and that this is an area where market forces do not operate effectively. Builders have incentives to keep first costs low and are resistant to investments in heat pumps, insulation, or solar energy devices that would be economical over the life of the building. Because the market for residential and commercial building does not operate to encourage energy conservation, the Ford Report suggests that projected energy savings are likely to be achieved by supplementing market forces with the following policies:

Consumer education

Adjusting the energy price structure

Government actions to overcome institutional barriers to technical innovations in the building industry

The Project Independence Report [PI-74] projects the U. S. primary energy consumption for the residential/commercial sector to grow from 24.8 quads to 42.9 quads between the period 1972 to 1985 -- an overall growth rate of 4.3 percent per year.

The point of listing a few of the conservation measures of the various scenarios is to emphasize that the residential/commercial sector represents a strong potential for significant savings through conservation measures -- both short and long term. The listing also points out that substantial and relevant studies have been recently completed regarding various conservation measures and their potential impacts.

TABLE 7.3-2 POTENTIAL ENERGY SAVINGS IN THE COMMERCIAL SECTOR (QUADRILLION BTU'S)

Modified from  
Ford Report  
[Ford-74-52]

Technical Fix vs. Historical Growth

	1985	2000	
Commercial energy use in HG scenario	16	23	
Potential Savings			Conservation Measures
Space heat	0.6	1.7	Heat pumps instead of resistance heat
	0.1	1.3	Total energy systems
	0.4	1.1	Insulation against heat loss
Air conditioning	--	0.2	Total energy systems
	0.3	0.3	Insulation against heat loss
Other		0.3	
Total savings	1.4	4.9	
Commercial energy use in FF scenario	15	18	

Note: The commercial sector's share of all energy processing losses are included in these numbers

Modified from National Petroleum Council Report [NPC-74-1,52]

Rank by Potential Yield	Conservation Measure	Total Potential		Assumed Achievable	
		Total (QBTU)	Percent of 1972 Commercial Sector	Total (QBTU)	Percent of 1972 Commercial Sector
1.	Establish a 68°F maximum occupied temperature level in apartments and hotel/motels and 65°F in commercial establishments, hospitals and nursing homes excepted.	1 084	9 0	358	3 0
2.	Establish a 5°F night setback below day levels in apartments and 10°F for commercial buildings during unoccupied hours, hospitals and nursing homes excepted.	688	5 7	227	1 9
3.	Caulk and weatherstrip around all windows and between building walls and window frames	591	4 9	089	7
4.	Scheduled maintenance on equipment and systems.	587	4 9	088	7
5.	Insulate ceiling, above or below roofs, using insulation having an equivalent "R" factor of 19	542	4 6	011	0
6.	Insulate sidewalls using insulation having an equivalent "R" factor of 11.	513	4 3	010	0
7.	Install storm sash, or high efficiency glass.	493	4 1	010	0
8.	Reduce lighting levels to a minimum acceptable level where possible.	292	2 4	096	7
9.	Establish minimum ventilating air requirements for occupancy periods and zero ventilation during unoccupied periods where possible.	159	1 3	024	2
10.	Use restricted flow shower heads (2 5 gallons per minute maximum)	097	8	015	1
11.	Establish a cooling comfort level of 78°F if basic energy is necessary	096	8	032	2
12.	Cease cooling of building at least one hour before termination of occupancy.	086	7	028	2
13.	Use automatic shutoff faucets in lavatories.	064	5	010	0
14.	Reduce water distribution pressure to a maximum of 25 p s i.	063	5	009	0
15.	Reduce temperature of general purpose hot water by 20°F (120°F minimum) except where dishwashers require otherwise.	059	5	019	1

ORIGINAL PAGE IS  
OF POOR QUALITY

It has been noted that energy conservation can be accomplished by: (1) belt tightening -- reducing use, (2) leak plugging -- using energy more efficiently, and (3) replacing -- substitution for scarce resources. The majority of the actions discussed in the National Petroleum Council report are short-term as "belt-tightening" measures that can be implemented in the time frame -- present to 1985. Many of the measures that "plug leaks" or increase efficiency will have major impacts in the mid-term range 1985-2000 (heat pumps serve as an example). Substitution actions (e.g. solar energy) are generally mid to long term considerations and in many cases are heavily dependent on new technologies.

Conservation by substitution is controlled by the pressures causing other types of conservation: (1) rising prices; and (2) unavailability of supply. These two pressures have initiated both the substitution of cheaper fuels (such as coal) and the investigation of abundant alternate fuel sources. The sudden surge of public enthusiasm for solar energy is a result of both the aforementioned pressures, with energy price increases making solar utilization ever more economically feasible.

In several areas of the country, the use of natural gas in newly constructed buildings, both residential and commercial, has been prohibited due to insufficient supply. This has caused much of the new residential housing to go "all-electric", a fuel substitution which is of dubious conservation value, depending on the generating plant source fuel. The shortfalls in natural gas supplies have also caused many interruptable commercial customers (those who must shut off their gas during peak demand periods) to begin looking for substitutional fuels such as oil and coal. If oil is the only substitution possible at present, this could, in turn, intensify the oil supply and price problem.

In summary, current conservation actions center on both near term improvements -- largely voluntary -- and longer term efforts -- requiring exploration of new modes and equipment for future use. The former measures can be employed by the individual home owner and building management persons. The latter generally involve technological improvements.

#### 7.4 GOVERNMENT ACTION STATUS

There is government involvement related to energy consumption in the residential and commercial sector at all levels -- federal, state and local.

Government actions affecting energy consumption range from the imposition of codes, ordinances and standards at the local and state level to federal laws and policies that regulate energy use and provide incentives for a particular mode of use or allocate energy and material resources.

At the federal level, the executive and legislative branches have proposed energy conservation actions which have direct or indirect impact on the residential and commercial sector. In January, 1975, the President proposed an energy conservation strategy which included an increase in the energy efficiency of major consumer products used in the home. In response, Congress has initiated legislation aimed at reducing the energy consumption of consumer products by the introduction of federal appliance labeling standards (see Chapter II). In addition, there have been other bills introduced in both the Senate and House which are largely or wholly devoted to energy conservation in the residential sector. In many cases the bills provide for voluntary compliance with energy conservation goals, but tax and depreciation incentives as well as mandatory compliance have been considered and in some instances provided.

Federally-funded energy studies have also addressed energy conservation in this sector. Examples are:

Energy Policy Project of the Ford Foundation

Project Independence

Westinghouse Energy Utilization Project.

Federal agencies also administer programs designed to effect energy conservation in the residential and commercial sector by providing information, funding research, and publishing standards. Some of the federal agencies actively involved in energy-related programs pertaining to the residential and commercial sector are:

Department of Health, Education and Welfare (HEW)

Department of Housing and Urban Development (HUD)

Federal Housing Administration (FHA)

Federal Energy Administration (FEA)

General Services Administration (GSA)

National Bureau of Standards (NBS)

Energy Research and Development Administration (ERDA)

Much of the effort of government in the area of energy is aimed at informing the consumer of the opportunities and benefits of energy conservation. Some of the government agencies (e.g. FHA and NBS) also set construction and building standards that affect energy consumption. ERDA is primarily concerned with research aimed at developing means of conserving energy. Areas in which they are sponsoring research which affects the residential and commercial sector are: advanced urban and architectural design, development and demonstration of technology to improve efficiency of energy use, and alternate energy sources. In the latter area, ERDA and NASA are presently implementing a nation-wide proof-of-concept experiment for solar heating and cooling involving thousands of residential and commercial buildings. The objective of this program is to develop and demonstrate solar heating systems by 1978 and combined solar heating and cooling systems by 1980. Also, ERDA is conducting a broad-based research program to investigate alternate fuel possibilities such as photovoltaic, solar thermal, geothermal, etc. Congressional support for programs concerning alternate fuels is demonstrated by the large number of bills submitted dealing with this subject.

At the state level, both executive and legislative branches have proposed, and in many cases enacted, legislation aimed at reducing energy consumption in the residential and commercial sector. State and local codes and standards also affect energy consumption (e.g. lighting codes) but not always with energy conservation in mind. In many states, proposals which would encourage installation of solar systems have been made. Tax incentives involving accelerated depreciation and tax exemption are the mechanisms being used. At the local level, city and county governments have recently been investigating the use of energy from trash incineration. Several municipalities are presently producing both electric power and heat from trash. There are also a number of state and local programs relating to appliance labeling. New York City and Massachusetts have already established labeling requirements. New Jersey, Florida and Minnesota are actively considering the establishment of similar statutes.

Specific examples of government actions at the federal, state and local level aimed at energy conservation are given in Appendix G.1.4.

## 7.5 SELECTED CONSERVATION ACTIONS

As part of the systems approach used in achieving our objective, the group developed a conservation action evaluation matrix for use in an initial qualitative assessment of various conservation actions in the residential/commercial area. Table 7.5-1 shows the matrix with an overall feasibility ranking of five actions selected by the group. Selection of the actions was dependent on an initial filtering of over 150 actions relevant to the sector through the evaluation matrix. (See Appendix G.2 for a listing of conservation actions considered, a descriptive listing of filtered actions, and a detailed description of the code used in selection of the actions.)

In general, a major consideration is that energy use in buildings is essentially a factor of physical design, construction practices and occupant

TABLE 7.5-1. CONSERVATION ACTION EVALUATION MATRIX

LEGEND:

"+" = favorable or positive  
 "-" = unfavorable or negative  
 "H" = high or large  
 "M" = medium  
 "L" = low or small  
 " " = no effect

CONSERVATION ACTION (Potential before 1985)	POTENTIAL SAVINGS	EASE OF IMPLEMENTATION	AVAILABILITY				IMPACTS			OVERALL FEASIBILITY	COMMENT
			CAPITAL	MANPOWER	MATERIALS	SOCIAL	POLITICAL	ECONOMIC	ENVIRONMENTAL		
Reduce consumption and increase efficiency of building and systems for Heating, Ventilating, and Air Conditioning (Group Action)	+H	+M	+M	+M	+M	-L	-L	?	+L	+M	<ul style="list-style-type: none"> <li>Specific actions include thermostat setting, HVAC maintenance, adding insulation, storm windows, caulking, improving HVAC equipment efficiency</li> <li>Save 7.1 quads/yr if 100% participation</li> <li>Most actions implemented in near future</li> </ul>
Reduce consumption and increase efficiency of domestic hot water systems (Group Action)	+L	+H	+H	+H	+H	-L		+L		+M	<ul style="list-style-type: none"> <li>Specific actions include lowering thermostat, reduce consumption, increase insulation</li> <li>Near term implementation</li> <li>Save about 1.5 quads/yr if all actions implemented by all consumers</li> </ul>
Install heat pumps in 100% of electrically heated single family residences built in the period 1975-85	+M	+M	+H	+H	+H	+L	+M	-L	+L	+L	<ul style="list-style-type: none"> <li>Would require extensive consumer education</li> <li>Save about 1 quad/yr by 1985</li> </ul>
Use solar energy for space heating and cooling and hot water heating	+M	+H	+H	+H	+H	+L	+M	+M	+L	+L	<ul style="list-style-type: none"> <li>Major implementation period in '85 to '95 time frame</li> <li>Savings about 2-6 quads/yr by 2000</li> <li>Assumed governmental backing continues</li> <li>Regional implementation is uneven</li> </ul>
Mandate government standards for lighting in all new and existing commercial structures (50-30-10 footcandles standard)	+H	+M	+H	+H	+H		+L	+L	+L	+M	<ul style="list-style-type: none"> <li>Project Independence predicts total potential savings of 50% or 0.65 quads/yr.</li> </ul>



needs and practices. Conservation then responds to the influence of the elements of each factor and the energy source. As a consequence, many specific actions are readily identifiable when we look at those aspects of physical design which include the conditions of the site, the orientation and configuration of the building, and the planning of the interior spaces. In addition, the materials of the building's skin and structure as well as the size, location and character of the openings in the skin must be considered.

Actions in the area of needs and practices involve comfort standards, design temperatures, ventilation requirements, lighting standards and programs of operation and maintenance. Also included are consumer practices such as thermostat settings, children and pets, work schedules, kind of activity, lighting, cooking and bathing.

In the actual filtering process, time frame was an important consideration, and all actions were qualitatively assessed as to their potential in the near time frame (1975-1985). One of the group's actions which was selected for an in-depth study -- use of solar energy for heating, cooling, and hot water -- has low potential in the near time frame. Nevertheless, solar energy will become increasingly important as a new energy source in the mid to long term and thus was our justification for consideration. Likewise, the selection of reduced lighting as a major consideration was based somewhat on its great potential for immediate savings in the commercial sector.

For a comprehensive analysis of each action in terms of requirements, potential savings in quads, and a detailed discussion of impacts, one should refer to Appendix G. A brief summary of the actions is in the following Section 7.5.1.

#### 7.5.1 UTILIZING SOLAR ENERGY FOR HEATING AND COOLING

The abundant availability of solar energy has been recognized as having great potential as a substitute for traditional fossil fuels for space heating, cooling and hot water heating. Projected savings attributed to solar energy based on varying levels of development are as follows:

1985: .4 to 2.0 quads/year

2000: 1.7 to 6.2 quads/ year

The lower figures (.4 and 1.7) represent a gradual expansion, while the higher figures (2.0 and 6.2) reflect maximum expansion possibilities. [MEGASTAR-74] While the technology necessary to implement solar heating/cooling is readily available and while public attitudes are favorably disposed towards solar implementation, the economics of installing solar systems as compared to conventional heating/cooling systems is the major mitigating factor to its widespread application. The current lack of a large market area to encourage the manufacture of solar components is also due to present, but rapidly changing, energy economics.

### Technology

Solar technology has been successfully demonstrated through several proof-of-concept experiments, and a small but rapidly growing solar energy industry is emerging. The federal government, having recognized the need to develop solar energy as an alternate source, is providing research and development funding to assist in promoting solar energy and the related industrial sector. Studies indicate [MEGASTAR-74, TERRASTAR-73, PI-74] that all necessary requirements (technical knowledge, manpower, materials, dollars) to successfully implement solar energy as an alternate fuel source are readily available.

### Impacts

The implementation of solar energy systems will produce impacts of significant magnitude in a variety of societal areas. Those related to the building industry who will be affected include homeowners, building contractors, financial institutions, insurers, architects, engineers, craftsmen, unions, local, state and national governmental agencies, and manufacturers and suppliers of component systems.

The widespread use of solar collectors will create impacts on land-use patterns and policies related thereto. These will include consideration for such elements as siting, shading, orientation, air space rights and landscaping.

Architectural considerations will include concern for esthetics when incorporating solar collectors into the building envelope. Also, building designers with solar expertise will be in greater demand than in the past. Engineering design disciplines will be required to become familiar with solar systems equipment and design requirements. Architects and engineers may require additional education in order to become familiar and qualified to design solar systems.

It will be necessary to give consideration to natural environmental hazards that may adversely affect the operation of solar systems. Phenom-

ena such as hail, wind, blown dust and other particulate matter will require consideration.

Political impact analyses will include an investigation into the role federal, state and local governments could play in assisting the development of a solar industry, assessing policies related to special interest groups (oil companies, utilities, consumers, energy producing states) and repercussions from legislative actions.

Social and psychological effects from implementing solar technology which result in changes in lifestyles and affect health and safety must also be investigated.

Economic impacts must be viewed as they affect the manufacturer, designer, builder and consumer of solar systems.

Overall, the successful implementation of solar energy technology requires an assessment and understanding of the complexities reflected by impacts and requirements associated with such an action.

#### 7.5.2 REDUCING CONSUMPTION AND INCREASING EFFICIENCY OF BUILDINGS AND SYSTEMS FOR HEATING, VENTILATING AND AIR CONDITIONING

Reducing consumption and increasing efficiency of buildings and systems for heating, ventilating and air conditioning is an action with many parts. Considering a 1972 consumption of 16.7 quads [NPC-74] and projected growth rates of 2.1% and 4.1% per year for residential and commercial energy, approximately 40% of the primary energy consumed by the residential/commercial sector can be saved. Potentially 7.1 quads per year can be conserved by a selection of specific activities. Tables 7.3-1 and 7.3-2 list activities which can produce this saving.

Those portions of the action which are operational in nature and require consumers to change their patterns can be instituted readily if consumers understand them and are interested in participating. Little money, material or manpower is required to carry out the activities. It is possible to build the changes into the system at small cost and to hire servicemen for maintenance if the consumer so desires.

The portions of the action which require physical design changes also require moderate investment of money, materials and manpower. Financial incentive is very useful in implementing the changes.

Changes in the heating, ventilating and air conditioning systems entail larger sums of money, materials and manpower. As costs increase, implementation becomes more difficult. Life cycle costing may help, especially if it can be demonstrated that initial cost differential can be recovered in a reasonable length of time. The concept of life cycle costing is one which must be emphasized to the consumer and explained in terms of the financial benefits to him in the long run. Initiation of an education program to inform the consumer of these potential benefits should be given high national priority. The obvious benefits of the action are seen in conservation of resources. If such conservation is reflected in dollars, then money is available for other desires. Conservation can supply peace of mind and reduce certain health dangers. It depends on substituting manpower for energy.

An example of a specific energy conservation action which demonstrates the concepts of life cycle costing and the potential for financial and energy conservation benefits is the installation of heat pumps in 100% of the new single family dwelling units to be built in the period 1975 to 1985 and projected to have electric space conditioning. This example also addresses the questions of consumer education and incentives to install energy conserving equipment, as well as the impacts that would result if such an action were implemented.

The analysis of this action indicated that an energy savings of 0.4 quads could be realized by 1985 with relatively minor impacts. A discussion of heat pump technology, the assumptions underlying the analysis, the analysis, and a discussion of potential impacts are given in Appendix G.2.

### 7.5.3 MANDATE GOVERNMENT STANDARDS FOR LIGHTING IN ALL NEW AND EXISTING COMMERCIAL STRUCTURES (50-30-10 footcandle standard)

According to Project Independence [PI-74,169], lighting accounted for about 10 percent of the total energy consumer in the household and commercial sectors in 1972, or about 1.8 quads. Approximately 73 percent of the energy used for lighting, or 1.3 quads, is consumed by the commercial portion. At the present time, lighting is the major important government energy conservation measure in effect in the buildings sector. As a result, the Federal Energy Management Program, of which "delamping" or reducing lighting levels is a major action, saved an estimated 2.7 trillion BTU's or \$760 million in fuel costs in fiscal year 1974.

The total saving potential after the establishment of mandatory federal standards, including federal monitoring and compliance mechanisms, would save an estimated .65-1.4 quads per year by 1980 -- 90 percent of which would be realized the first year.

## Requirements

An immediate beneficial effect would result from the observance of the standard with only small capital requirements needed from the commercial sector for implementation. However, an estimated \$25 to \$50 million per year would be spent at the federal, state and local levels for administrative and compliance costs. Manpower and material requirements within the sector would be small.

## Impacts

The action would require federal, state and local legislation or regulation, and the 50-30-10 footcandle standard would become a condition attached to federal grants and mortgages. The policy would result in some reduction in sales by bulb and lighting equipment manufacturers -- perhaps as much as 15-25 percent. This, of course, would result in an employment decrease for these manufacturers, but the decrease would be buffered overall by an increased need for maintenance people to implement the program and for government people to carry out enforcement.

Reduced night-lighting could cause a higher incidence of crime and vandalism, resulting in increased expenditures for repair and increased security personnel.

Changes would be required in the heating and cooling systems and practices. For example, one would have to consider that some all-electric buildings use lighting as a source of heat and that reduced lighting would impact wet or dry heat or light systems.

One distinct advantage in reduced lighting would be the savings resulting from the subsequent reduced energy consumption due to the resulting decreased demand for air conditioning.

Reduced lighting would probably have a significant effect on utility load factors, especially in large metropolitan areas.

Designing new buildings to meet the 50-30-10 standard and to generally save energy by reducing the lighting demands means a consideration of a multitude of requirements and subsequent impacts. Many of these are discussed in detail in Appendix G.4, where an in-depth analysis of the above is given.

#### 7.5.4 REDUCED CONSUMPTION AND INCREASED EFFICIENCY OF RESIDENTIAL HOT WATER SYSTEMS

In 1970, 1.7 quads, or approximately 4% of the total national energy consumption, was used for hot water heating. Under the assumptions of no major technological, price, or governmental policy change, consumption is projected to be 2.3 quads in 1985 [PI-74,1]. The analyses and potentials of five actions are presented in Appendix G.5. They are to reduce hot water usage by: (1) lowering the tub bath level by one inch (or equivalent for shower) (2) use of cold water detergents (3) washer replacements in leaky faucets (usually hot water), (4) reduce thermostat settings on hot water heaters, and (5) increased insulation of hot water heaters. The 1970 total potential for savings of all actions was greater than one quad with a total per family saving of nearly fifty dollars per year. The potential is projected to be nearly one and one-half quads in 1985.

Only action number 5, increased insulation, has a substantial material requirement; it is approximately 30 square feet of 3 inches insulation/hot water heater at an estimated cost of 5 dollars. With the estimated saving of 12 dollars per year, this cost would be regained in 5 months. If all family units (70 million in 1972 [PI-74,5]) insulated their hot water storage tanks, the insulation requirements would be small compared to that for new house construction (cf. Appendix G.5).

It is believed that the major obstacle to implementing the five actions is public acceptance. The one and one-half quad potential savings, at a very small cost in manpower and other requirements, strongly warrants a public education program.

For the magnitude of benefits, the impacts are small. As noted above, the material requirements would slightly increase the demand for insulation in the housing market. Water temperatures of 140°F and the bactericidal action of dish water detergents are adequate for removal of pathogenic bacteria, if the dishes are not allowed to set before rinsing. For automatic dish washers, there is insufficient study to insure safety at lower temperatures.

A detailed analysis of the five selected actions for reducing consumption and increasing efficiency of residential hot water systems is included in Appendix G.5.

## 7.6 ASSESSMENTS

In the previous sections of this chapter, specific conservation actions were identified, their requirements found, and the impacts discussed. Each action was treated as if it was to be implemented alone, without regard to any other proposed action. The purpose of this section is to analyze the group of actions in the residential/commercial sector assuming simultaneous implementation. The analysis of all actions at once allows identification of possible areas of conflict between various actions, as well as possible areas where actions reinforce one another.

The major constraint on cross-action assessment is that the actions being considered must be implemented in the same general time frame. However, it is possible to realize from this approach that those actions in an early time frame might help or hinder the implementation of an action in a later time frame.

The cross-action assessment matrix shown in Table 7.6-1 lists the five major conservation actions chosen for study by the residential/commercial task group. The box at the intersection of columns and rows indicates whether the two actions are

- (C): complementary, independent, or reinforcing
- (T): in need of a trade-off, or mildly interfering
- (I): strongly interfering, or difficult to implement simultaneously
- (U): uncertain as to how they interact.

As seen on the matrix, no one of the actions is complementary with all four of the other actions (read down and/or left from the "dot" box to see how an action interacts with all the others).

Five of the possible double-action combinations appear to be complementary or they can be implemented independently. The "lighting standards in commercial buildings" and "heat pump installation in residences" actions are an example of apparently unrelated actions. "Increasing building efficiency" and "using solar energy" are actions which would complement one another if instigated concurrently.

An example of a trade-off interaction would implement "using solar energy" and "heat pumps" together. The use of solar-assisted heat pumps has been suggested by many and seems a viable combination of conservation measures. The "commercial lighting" and "reduce consumption in buildings" actions were deemed interfering because many commercial buildings have a significant portion of their heating load supplied by the lighting.

In conclusion, it should be noted that the assessment of actions should not only be carried out at the sector level, but also at the overall economy level. This will be the focus of Chapter 8, the integration of all sector actions into an overall analysis.

TABLE 7.6-1 RESIDENTIAL/COMMERCIAL SECTOR CROSS-ACTION ASSESSMENT MATRIX

## LEGEND:

"C" means the two actions complement each other

"T" means the actions need a tradeoff (minor interference)

"I" means the two actions interfere with each other

"U" means it is uncertain how the actions interact

Reduce consumption and increase efficiency of buildings and systems for HVAC (Group Action)	O				
Reduce consumption and increase efficiency of domestic hot water systems (Group Action)	C	O			
Use solar energy for space heating and cooling and hot water heating	C	C	O		
Install heat pumps in 100% of electrically heated single family residences built in the period 1975-85	C	U	T	O	
Mandate government standards for lighting in all new and existing commercial structures (50-30-10 footcandles standard)	I	C	T	C	O
	Reduce consumption and increase efficiency of building and systems for HVAC (Group Action)	Reduce consumption and increase efficiency of domestic hot water systems (Group Action)	Use solar energy for space heating and cooling and hot water heating	Install heat pumps in 100% of electrically heated single family residences built in the period 1975-85	Mandate government standards for lighting in all new and existing commercial structures (50-30-10 footcandles standard)



## CHAPTER 8. INPUT-OUTPUT ANALYSIS OF SOME SECTOR ACTIONS

Selected conservation actions, discussed in depth in Chapters 4 through 7, are brought together in this chapter and assessed as a group. Particular emphasis is devoted to identifying secondary or indirect impacts. Preliminary results obtained from the ECASTAR energy input-output model suggest that the impacts of energy conservation actions can be grossly misrepresented if secondary impacts are not included in the assessment. A methodology which stresses the importance of secondary and multiple interactions permeates the underlying philosophy of this chapter.

### 8.1 INTRODUCTION

The ECASTAR group realized the necessity of viewing potential conservation actions from at least two perspectives. The first perspective was at the task group level. At this level the economy was dissected into four principal areas; the energy industry, manufacturing, transportation, and residential/commercial sectors. This disaggregation of the economy afforded the group the opportunity to concentrate on the details, requirements, and feasibility of specific conservation proposals. At the task group level hundreds of actions were examined and weighed as to their potential importance and applicability. The task group organization permitted a systematic screening for major actions. Representative actions were presented by task group area in the previous four chapters.

The second perspective focused on the aggregate economy. At this level the group sought to assess more completely the probable impacts that a conservation action or set of conservation actions would have on the **economic**, social, and political environment. Impacts could only be partially evaluated at the task group level. Actions undertaken in one sector were likely to constrain or impinge upon actions undertaken in another sector. By adopting a global perspective the compatibility and effectiveness of conservation actions (and the resulting probable perturbations to the economy) could be displayed and assessed. Without this perspective it was thought that any conclusions regarding the potential contribution of an action would be premature.

In this chapter some of the major actions that were presented in the sector chapters are analyzed further, from the total economy perspective. At this level of analysis the focus shifts to an examination of conservation policy as well as to the total effectiveness of conservation actions.

A model was needed that both bridged the four sectors and permitted aggregation of the sectors back to the integrated economic whole. Such a requirement is formalized in the input-output model. The ECASTAR group constructed an input-output "model" to serve as a mode of analysis and to provide a structure within which conservation policy could be evaluated.

Specific in-depth analysis is a secondary emphasis of this chapter. This consideration was partly dictated by constraints on time and manpower available to the group. In this chapter the analysis of a few potential actions is really of secondary interest. For, before an investigation can get started, the methodological and analytical underpinnings of the investigation have to be firmly charted. This chapter describes one such approach to the assessment of actions.

## 8.2 THE ECASTAR ENERGY INPUT-OUTPUT MODEL

The ECASTAR energy input-output model consists of thirty sectors. Represented in this group of thirty are five energy producing sectors, fifteen manufacturing industries, two residential and commercial sectors, and eight service industries. The list of sectors is given in Table 8.2-1.

As input-output models go, the ECASTAR model is quite modest. The U. S. Department of Commerce, for example, has constructed a 378 sector representation of the economy. Whereas a large model permits the display of considerable detail, its size makes it cumbersome when the focus of attention is policy analysis. The ECASTAR model is large enough to permit the tracing of major impacts and interindustry repercussions and yet is small enough to be manageable and amenable as a tool suitable for various policy simulations.

Input-output analysis is inherently a static analysis. However, conservation actions are likely to be felt over a period of time, suggesting that the impacts of the actions will operate on the dynamics of the system. The ECASTAR group designed their model so that it was capable of being used in an iterative procedure. For example, the first phase would be identifying and measuring the direct impacts on the structure of the model (economy) resulting from the enactment of a policy or conservation action. The second phase would be the feed-back of these direct impacts into the model, a sort of response adjustment, to determine the scope and magnitude of the indirect impacts. It is these indirect impacts which are very important and often overlooked. Time and other constraints made it impossible for the ECASTAR group to explore, in depth, the iterative process. However, the group recommends that this approach be thoroughly investigated. A modest sized I-O model would be best suited for the analysis of the dynamics of the system. In a large system one can easily become overwhelmed with too much detail and too many spurious relationships. Examination of an action in the context of a modest sized, manageable model facilitates the use of a more complex model for detailed investigations.

TABLE 8.2-1 INDUSTRY GROUPS CONTAINED IN THE ECSTAR INPUT-OUTPUT MODEL

<u>Group</u>	<u>Group Title</u>
1	Livestock, agricultural products, forestry products and related services (SIC 01-09)
2	Iron, nonferrous mining (SIC 10)
3	Coal mining (SIC 11-12)
4	Crude petroleum and natural gas (SIC 13)
5	Stone, clay mining; chemicals and fertilizer mineral mining (SIC 14)
6	New construction, maintenance and repair construction (SIC 15-16)
7	Ordnance and accessories (SIC 17-19)
8	Food and kindred products, tobacco manufactures (SIC 20-21)
9	Textiles, apparel, textile products (SIC 22-23)
10	Lumber, wood products, furniture (SIC 24-25)
11	Paper and allied products (SIC 26-27)
12	Chemicals and allied products (SIC 28)
13	Petroleum refining and related industries (SIC 29)
14	Rubber, leather products (SIC 30-31)
15	Glass, glass products, stone and clay products
16	Primary Metals (SIC 33)
17	Metal container, fabricated metal products (SIC 34)
18	Machinery (SIC 35)
19	Household appliances (SIC 363)
20	Electric lighting and wiring equipment (SIC 364)
21	Miscellaneous electrical machinery (SIC 36)
22	Motor vehicles and other transportation equipment (SIC 37)
23	Miscellaneous manufacturing (SIC 38-39)
24	Transportation and warehousing (SIC 40-47)
25	Communications, except radio and TV (SIC 48)
26	Electric utilities (SIC 491)
27	Gas utilities (SIC 492)
28	Water and sanitary services (SIC 494)
29	Wholesale and retail trade (SIC 50-52)
30	Other services, government enterprises (SIC 60-80)

The ECASTAR I-O model was constructed by aggregating the interindustry transactions contained in the U. S. Department of Commerce 1967 input-output table [SCB-74]. The Department of Commerce input-output model is presented in Appendix H and categories of aggregation are discussed. All dollar values reported will be in terms of 1967 dollars unless otherwise indicated. Direct energy use values were obtained from [CAC-75]. From this data energy transactions matrices were computed. Labor statistics were obtained from the Bureau of Labor Statistics Bulletin No. 1831. A discussion of how the dollar transaction matrix was converted to a labor or energy transactions matrix is reserved for Appendix C.

The ECASTAR model is capable of tracing the impacts of an action in three dimensions: dollars, BTU's of energy, and labor employment. Other dimensions of analysis, social and political for example, are not easily integrated into the I-O structure. An analysis of impacts in these dimensions must be handled through different modes. Table 8.2-2 presents the value of output, value of final demand, direct energy transacted, and labor employed in each of the 30 groups in 1967.

### 8.3 THE BASE CASE

The actions investigated in this chapter will be evaluated in two contexts. The first will be relative to 1967. The second will be relative to a base case--the BLS projections of the structure of the U. S. economy in 1985[BLS-75]. The aim is to present the positive and negative aspects of energy conservation. The BLS projections mirror historical growth. The advantage of the BLS report is that it contains projected final demands for each industry group.

The general assumptions underlying the BLS projections are:

An unemployment rate of approximately 4% and an annual rate of 3% in the GNP price deflator.

The institutional framework of the economy will not be greatly altered.

Expenditures diverted to solving air and water pollution, waste disposal, urban congestion etc. will not have more than a marginal effect on overall economic growth.

The U. S. energy supply-demand balance will follow the projections contained in "U. S. Energy Through the Year 2000". [Dupree-72] which implies a continued reliance on imported oil.

TABLE 8.2-2 LEVELS OF OUTPUT, ENERGY,  
AND EMPLOYMENT - BASE CASE, 1967

TABLE 8.2-2

Group	BTU's Directly Purchased x10 <sup>15</sup>	Final Demand \$ x10 <sup>9</sup>	Total Output \$ x10 <sup>9</sup>	Total Employment x10 <sup>3</sup>
1	1.107	9.301	63.793	4178
2	.111	.255	3.384	81
3	.033	.618	3.163	147
4	1.805	.028	15.031	297
5	.214	.240	3.382	124
6	1.291	85.584	103.280	3985
7	.074	6.925	10.731	317
8	.943	70.970	97.391	1912
9	.359	22.094	47.484	2384
10	.231	7.251	21.392	1145
11	1.242	8.624	44.882	1824
12	2.902	13.992	47.102	1003
13	2.931	12.870	26.975	183
14	.217	7.090	19.139	872
15	1.232	1.161	14.827	634
16	4.427	2.447	52.593	1351
17	.031	4.658	37.677	1386
18	.370	35.293	65.124	2448
19	.042	3.956	5.450	175
20	.027	.965	4.118	202
21	.109	16.441	28.614	1167
22	.355	49.545	73.544	1954
23	.785	11.900	20.327	906
24	3.053	20.653	52.823	2838
25	.029	10.094	19.328	852
26	11.382	7.065	18.604	446
27	18.501	3.991	13.432	163
28	.098	1.546	3.116	46
29	2.525	120.815	163.365	16153
30	2.929	250.207	428.994	17101

Thus the BLS projections were made before the "oil embargo" and "energy crisis." Needless to say, the projections are being revised. Nonetheless, the BLS projections serve well to characterize historical growth. Revised estimates of the U. S. economy in 1980 and 1984 recently published by [Chase-75] provide the opportunity for estimating the impact on energy use and thus the need for conservation resulting from changing patterns of final demand. The energy sectors explicitly contained in the I-O model are coal, crude petroleum and natural gas, refined petroleum, electric utilities, and gas utilities. Other sources of energy such as nuclear, solar, and geothermal are not explicitly contained in the model. Considering a time horizon of 1985, this omission may not be crucial. Nevertheless, energy shortfalls uncovered by use of this I-O model should be evaluated in the context that some additional supplies were not included.

Projected output levels and final demands for 1980 and 1985 are presented in Table 8.3-1. The energy requirements for 1980 and 1985, assuming this historical growth, are summarized in Table 8.3-2.

The case for conservation can be seen clearly on Figure 8.3-1. The bottom lines refer to 1985 projected energy demand. The solid lines refer to projected energy supplies. The dashed area indicates the projected shortfall. Conservation is aimed at mitigating the size of the shortfall.

#### 8.4 ACTIONS

Four actions were selected from Chapters 4-7 to demonstrate the applicability of the I-O model in assessing impacts of conservation actions. Unfortunately, time and budget limitations prevented the ECSTAR group from analyzing all the major actions contained in Chapters 4-7. Another set of actions which have been linked with proposed legislation is discussed in Chapter 9 of this report.

The four actions considered in this chapter are:

- A 30% increase in fuel efficiency applied to the chemicals and refined petroleum groups.

- A 40% reduction in fuel used in the transportation and warehousing group.

- Manufacturing of smaller automobiles using 25% less steel and rubber

- A communications/transportation tradeoff.

These actions were applied both to 1967 levels of output and to 1985 projected levels.

TABLE 8.3-1 BUREAU OF LABOR STATISTICS PROJECTED  
FINAL DEMAND IN 1980 AND 1985(1963 DOLLARS)

Group	1980 (\$ x10 <sup>9</sup> )	1985 (\$ x10 <sup>9</sup> )
1	14.530	16.237
2	.353	.459
3	.943	1.050
4	.049	.046
5	.417	.520
6	125.305	148.419
7	7.013	8.336
8	93.093	104.441
9	33.643	37.977
10	11.791	13.321
11	14.825	17.597
12	32.582	40.515
13	22.453	26.805
14	11.583	13.598
15	1.813	2.084
16	4.804	5.821
17	6.784	7.942
18	61.957	76.874
19	8.502	10.306
20	1.937	2.369
21	30.409	37.151
22	91.657	104.347
23	21.469	26.499
24	36.787	43.814
25	25.858	33.921
26	19.741	23.879
27	7.939	9.394
28	1.819	1.847
29	194.870	226.800
30	301.524	344.517

TABLE 8.3-2. ENERGY REQUIREMENTS FOR 1980 AND 1985  
BASE CASE  
(Quadrillion BTU's)

	Coal	Refined Petroleum	Natural gas	
1967 Base	14.8	26.1	18.45	5
1980	24.6	34.9	39.9	9
1985	29.0	49.0	44.0	12

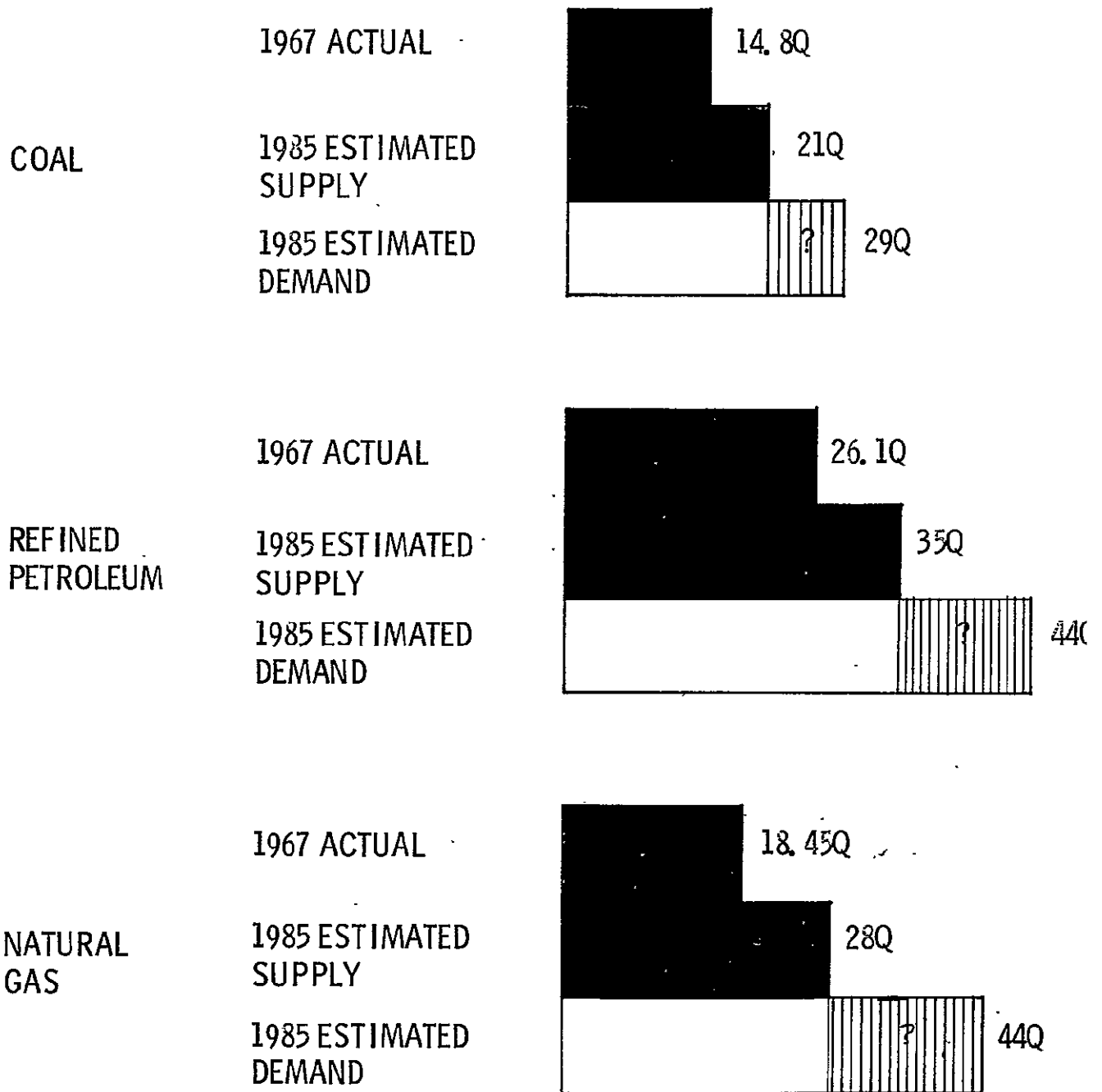


FIGURE 8.3-1. THE CASE FOR CONSERVATION



#### 8.4.1 INDUSTRIAL FUEL EFFICIENCY

Using advanced technology it was suggested that by 1985 fuel efficiencies can be increased by 30% in the chemical and petroleum refining industries (see Chapter 5). The impact on total BTU's purchased will be 30% times the proportion of transacted energy going for combustion purposes. A rough, conservative estimate for the chemicals and refining sectors is 70% [CAC-74]. Thus, the direct impact on total BTU's will be a decrease of approximately 20%. Table 8.4.1-1 presents a comparison of the direct impacts that a 20% reduction in fuel use would have in 1967, 1980, and 1985.

If these reductions were achieved with no change in output there would be no major identifiable indirect impacts. As a result of these lower energy requirements, the amount available to other sectors would increase. In 1967 this would amount to nearly 1 quad--or 5% of total industry use.

The use of advanced technology means that the transacted BTU per dollar output value would be lowered. From Table 8.2-2 we note that a majority of the output produced by the chemical and petroleum refining sectors is sold as inputs to other industries--not directly to final markets. Thus, the increased efficiencies obtained in these two sectors are distributed throughout the interindustry structure. An increase in the final demand for a product which has a large amount of imbedded chemical product input implies that the overall product efficiency will increase, if the energy imbedded in the inputs is "charged" to the output sector (see Appendix E). Through this accounting scheme, the combined impact of a change in final demand and the increased fuel efficiency can be assessed. Final demand, not total output, drives the demand side of the system. Total output is of interest primarily when actual output is less than estimated total output. To put it another way, knowing that the BTU per dollar of chemical output has declined is of little value until you know where and how much of it ends up in other industries. A change of the energy accounting scheme helps identify energy flows, and particularly those that are "targets of conservation potential." The structure and composition of final demand are quite important when impacts of engineering actions are evaluated. An extreme example would be a process which cuts energy consumption by a large percentage. If this industry has a small, static level of final demand, the process improvement may not make even a marginal impact.

#### 8.4.2 REDUCTION IN FREIGHT FUEL REQUIREMENTS

A 40% reduction in the transportation and warehousing group, which includes railroads, motor freight, air transport, and water transport, would imply savings of  $1.1 \times 10^{15}$ ,  $1.74 \times 10^{15}$ ,  $2.06 \times 10^{15}$  BTU's in 1967, 1980, and 1985 respectively. For given prices of fuels, a 40% reduction of fuel use has the added impact of moderating the cost of transport and hence ultimately the cost of final goods and services.

TABLE 8.4.1-1.  
 DIRECT FUEL SAVINGS BROUGHT ABOUT BY A 30% INCREASE IN FUEL EFFICIENCY  
 (Quadrillion BTU's)

	1967	1980 <sup>a</sup>	1985 <sup>a</sup>
Chemical and Allied Products	.60	1.12	1.46
Petroleum Refining	.35	.56	.69

a. Relative to the base case projections [Dupree-72].

Since prices cannot be explicitly estimated from the I-O model, some potential impacts can only be suggested. If fuel use in transportation decreases, what happens to transport prices? Would there be any shift to rail and water transport? There are many indirect impacts to examine if any substitution is involved.

#### 8.4.3 ALTERED AUTOMOBILE REQUIREMENTS

In 1967 the automobile sector produced total output valued at 73.5 billion(1967) dollars. In producing that output the industry required over 6 billion dollars of input from the primary metals industry and over 1 billion dollars of input from the rubber and allied products sector. A 25% reduction in steel and rubber required by the transportation manufacturing industry would result in a 3% decline in output from primary metals and a 1.5% decline in output from rubber and allied products. The direct energy impact would be a reduction of  $.3 \times 10^{15}$  BTU's.

These reductions imply a reduction in employment of 40,000 in primary metals and 13,000 in the rubber industry. Note that these numbers are rough estimates only. - The level of aggregation used in the ECSTAR model does not permit a refinement in the estimates--one would have to utilize a larger I-O model.

A reduction in output of this magnitude causes subsidiary impacts in the economy. What happens to final demand as a result of a shift away from heavier cars? Suppose the value of transportation output stays constant. Then the reduction in steel and rubber implies decreases in the final demands for all sectors included in the model. The cumulative effect of the reductions in primary metals and rubber amount to .8% of 1967 GNP. This reduction would be accompanied with a decrease of over 400,000 in total employment. The new levels of final demand imply new levels of output. This iterative process would continue until all the indirect effects were included. If the trend to smaller automobiles was accompanied with decreased sales and less auto production, the cumulative effect on GNP would be quite substantial. So important are these sectors that actions adversely affecting their output could quickly throw the economy into a substantial recession. The recent slump in the auto industry provides a perspective on how interdependent industries are in this economy.

The auto example shows the possibility of many potentially important indirect impacts. For example, if primary metals production is down and workers are laid off, what subsidiary impacts are likely to play havoc with the pattern of final demand? Sales of durable consumption items usually do not fare too well in sluggish times, nor do auto sales. If smaller cars are priced on a level with larger cars such that sales do not increase, the accumulation of inventories (excess supply) impacts on the production cycle. A 20% decline in auto sales will reimpact on primary metal production, this time with more force, as well as on all other sectors. It would be a mistake to peg economic growth solely with energy growth. While the two are casually related, there is no fixed relationship governing GNP growth. A recession brought about by adopting questionable actions in the name of conservation would be an extremely myopic and costly strategy.

#### 8.4.4 ALTERNATIVE GROWTH ASSUMPTIONS

The direct impacts of the actions which were just highlighted are presented in Tables 8.4.4-1 and 8.4.4-2 for 1967 and 1985 respectively. Some care should be used in interpreting the entries in these tables due to the level of aggregation employed. The 1985 numbers reflect the historical growth assumption. The energy sectors were not included in these tables so that attention could be focused on non-energy industry impacts. The effect of substitution from gas to coal and from oil to coal is explored in Chapter 9.

The energy savings in 1967 amounted to a little more than 2.5 quads. This would have been accomplished with a reduction of employment of a little over 600,000. In 1985, the projected energy savings was over 4 quads at an employment cost of over 1 million. If indirect effects were also accounted for, the total effects would have indicated more energy saved with more unemployment.

It has been stated that the objective of investment and growth is to keep the real GNP growing--not to reapportion shares in a constantly decreasing GNP [Simon-75]. Conservation aimed at increasing efficiency may have primarily beneficial direct impacts. Conservation achieved through changing the structure of demand (including substitution of energy sources and reducing demand) may well alter the size and distribution of the GNP. It was argued earlier in Appendix E that policy which impinges on production of output and the composition of final demand needs to be carefully scrutinized for hidden and indirect, but nevertheless major, impacts.

That a changing structure of final demand impacts on energy use can be demonstrated by comparing the energy required to satisfy the level of demand forecasted for 1980 by Chase Econometrics with that level of demand assumed in the historical growth case for 1980. This comparison is presented in Table 8.4.4-3.

#### 8.4.5 COMMUNICATION - TRANSPORTATION TRADE OFF

The possibility of conserving energy by substituting communications for transportation was discussed in Appendix F.5. What would happen to employment and BTU use if 1 billion dollars were shifted from the transportation and warehouse sector to the communications sector? Most of the substitution would originate in industry. The transportation-warehouse group, number 24, included travel for business purposes. No other category, except possibly wholesale/retail trade, number 29, appeared to be directly impacted by the substitution.

Direct additional energy use in the communications' sector would increase by  $1.0 \times 10^{12}$  BTU's. Energy saved in sector 24 would be approximately  $60.5 \times 10^{12}$  BTU's, or a 60 fold savings. A one billion dollar increase for communications would imply an additional 44,000 jobs. A one billion dollar decrease in transportation would imply a loss of close

TABLE 8.4.4-1  
COMPARISON OF BTU AND LABOR REQUIREMENTS  
WITH AND WITHOUT CONSERVATION ACTIONS-  
DIRECT CHANGES  
1967

Sector <sup>a</sup>	BTU's No Conservation x10 <sup>15</sup>	BTU's Conservation x10 <sup>15</sup>	Labor No Conservation x10 <sup>3</sup>	Labor Conservation x10 <sup>3</sup>
1	1.10	1.08	4178	4124
2	.11	.10	81	87
5	.21	.19	124	114
6	1.29	1.26	3985	3904
7	.07	.06	317	283
8	.94	.92	1912	1879
9	.36	.35	2384	2324
10	.23	.22	1145	1118
11	1.24	1.08	1824	1757
12	2.90	2.35	1003	903
14	.22	.21	872	846
15	1.23	1.06	634	588
16	4.43	4.05	1351	1240
17	.31	.30	1386	1366
18	.36	.35	2448	2370
19	.04	.04	175	173
20	.03	.02	202	189
21	.11	.10	1167	1160
22	.36	.32	1954	1771
23	.78	.76	906	878
24	3.05	2.07	2838	1925
25	.02	.02	852	811
28	.09	.09	46	44
29	2.52	2.48	16336	15875

a. Energy sectors excluded to emphasize indirect impacts.

TABLE 8.4.4-2  
COMPARISON OF BTU AND LABOR REQUIREMENTS  
WITH AND WITHOUT CONSERVATION ACTIONS  
DIRECT CHANGES  
1985

Sector <sup>a</sup>	BTU's No Conservation x10 <sup>15</sup>	BTU's Conservation x10 <sup>15</sup>	Labor No Conservation x10 <sup>3</sup>	Labor Conservation x10 <sup>3</sup>
1	1.70	1.66	6445	6302
2	.21	.20	151	149
5	.41	.38	237	224
6	2.18	2.16	6734	6716
7	.07	.06	318	318
8	1.38	1.33	2806	2710
9	.62	.60	4103	4087
10	.41	.40	2050	2026
11	2.16	1.91	3169	2813
12	6.42	5.86	2208	2014
14	.41	.40	1657	1629
15	2.02	1.80	1039	926
16	8.73	7.84	2666	2393
17	.58	.57	2584	2545
18	.77	.76	4104	4080
19	.10	.10	428	427
20	.05	.05	391	390
21	.23	.22	2443	2437
22	.69	.69	3818	3806
23	1.63	1.61	1860	1852
24	5.66	5.09	4803	4746
25	.05	.04	1750	1699
28	.14	.13	65	64
29	4.63	4.49	29598	28975

a. Energy sectors excluded to emphasize indirect impacts.

TABLE 8.4.4-3  
ESTIMATES OF ENERGY  
DEMAND FOR 1980 BY SOURCE FOR HISTORICAL GROWTH  
AND REVISED GROWTH SCENARIOS  
(Quadrillion BTU's)

	Coal	Refined Petroleum	Natural Gas	Total
historical growth	24.6	34.9	39.9	99.4
base estimates	25.4	30.2	30.4	86.0

to 54,000 jobs. The indirect effects would center on communication equipment manufacturing, fabricated metals, chemicals and allied products, transportation manufacturing, primary metals, petroleum refining, and stone, clay, and glass products. The indirect effect on the final demand for manufactured trucks and automobiles is a decline of nearly 25 million dollars; the indirect effect on wholesale and retail trade is a decline of 85 million. These effects together amount to a decline of over 10% of the initial output change. These indirect negative impacts are not offset by positive impacts accrued by increasing output in the communications sector.

The picture becomes more complicated if the structure of retail and wholesale trade is greatly altered. For this type of trade off to make an imprint a change in final demand for greater than 1 billion dollars is required. At higher levels the inputs needed by an expanding communications industry may well be the bottlenecks. The input-output model can be used to simulate alternative magnitudes of trade offs--which would yield measurement of the indirect requirements. Growth in the communications sector has a different implication than does growth in the transportation sector. These changes would need to be examined closely. This is but one example which suggests that conservation can be achieved by altering the sector shares of GNP; thus altering the composition, not the size, of the economic pie. It is not clear that effecting a redistribution permits one to keep the same sized pie. The communications/transportation trade-off suggests that, primarily because of indirect effects, the pie would shrink, i.e. GNP would decline.

## 8.5 SUMMARY

The conservation actions which were just discussed could not be analyzed in the depth that the ECASSTAR group desired. The time limitation dictated that only a few examples could be displayed. Even for these, all of the impacts, direct and indirect, could not be examined. While detailed estimates of these impacts would be useful, it is perhaps just as important to realize that there are indirect impacts to consider. A complete assessment strategy should look for indirect impacts and include them in the assessment.

The input-output structure can be used to both identify impacts and to estimate their magnitude. The following strategy is suggested from the examples in this chapter:

Given a vector of final demands, solve the I-O model for required output levels.

Solving for output requirements allows one to uncover potential bottlenecks in supply. For example, if the solution to the model had as a requirement that water utilities were to grow by over 100% in five years, the desirability of the solution would be tempered by the unlikely output requirement from water. Other final

demand vectors, each reflecting an assumption(s) about growth in the economy, could be imposed on the model. The sensitivity of the required output levels could be studied through these simulations.

Pick a set of possible conservation actions which can fit into the structure of the I-O model.

These actions which change the direct requirements' matrix should be addressed one at a time so that their partial effectiveness can be determined. Afterwards, the set as a whole can be analyzed by the model.

Some actions do not change the dollar direct requirements' matrix but will change the BTU direct requirements' matrix. Increasing fuel efficiencies through combustion improvements, for example, should alter only the BTU direct requirements' matrix or the vector of BTU's per unit of output. Other actions, for example, building automobiles with less steel, change all the direct requirements' matrices.

If any requirements' matrix is changed, the system should be resolved for total output. If the vector of total outputs changes, then indirect impacts can be investigated by using the changed total output vector to solve for the new implied level of final demand.

The sum of the final demand vector is estimated GNP. This implied level should be compared to earlier projections. For each iteration total required energy should be displayed along with total implied employment and GNP.

- The model can be used to study the effect on energy demand of sectors having different growth rates. For example, given assumptions about population and GNP growth, what is the ideal growth rate for the transportation sector?

The idea here is that if one sector is growing too fast, or in spurts, and is involved in large indirect interdependencies with other sectors, fiscal and/or monetary policy may be brought in to mitigate the magnitude and duration of the potential swings. Growth is linked to final demand and energy required to satisfy that final demand. Refer to Appendix E for a discussion of energy cost and final demand.

The model can be used to identify links in the input chain where product substitution may be recommended. The substitution of aluminum for steel may or may not be warranted. The energy direct requirements' matrix should be carefully screened. In terms of BTU's per dollar of output, lumber is six times less energy intensive (direct requirements) than certain plastics. Should lumber and wood products be substituted for plastics instead of the historical trend of plastic substitution?



## CHAPTER 9. NATIONAL ENERGY CONSERVATION

This chapter analyzes a set of energy conservation actions that cut across all sectors of the economy. The purpose of analyzing such a set of actions is to illustrate the methodology of the Design Group, i.e., that all actions under consideration must be analyzed systematically and as a whole. In this manner, total impacts can be assessed.

The actions considered were as follows: (1) roll back the price of newly discovered oil; (2) freeze gasoline production for 3 years at 1972 levels; (3) mandate automobile mileage improvements; (4) require industry to improve energy efficiency; (5) require manufacture of household appliances with greater efficiency; (6) force conversion of many power plants from gas and oil to coal. The results, based on the Input-Output analysis technique, showed that considerable gas and oil would be saved by forcing switches to coal. However, the large scale switch to coal was shown to require greatly increased outputs from many other industries. These outputs (called indirect requirements) in turn required more energy. It was estimated that nearly 2.5 quads of additional coal were needed to produce these indirect requirements.

Also, the indirect requirements created more jobs. If the switch to coal use is the only action considered, the increase in projected employment is quite large. If the switch to coal is assessed in conjunction with steps (2) - (5), the indirect requirements and consequently increased employment are significantly less. This illustrates the Group's philosophy that the impacts of energy conservation can be unexpected and large. Consequently, all actions must be carefully analyzed before they are implemented.

### 9.1 INTRODUCTION

Many believe that economic growth is closely associated with rising energy inputs from fossil fuels. Considering the fact that these inputs are ultimately limited by eventual exhaustion and, perhaps more importantly, that they are unequally distributed should have warned us as a nation to proceed cautiously in using fossil fuels to stimulate economic growth. Perhaps, the Arabs did us a good turn without quite intending to. The fact is, they forced us to think about increasing fossil fuel consumption and the attendant rising cost of energy now, when there is time to do something about it. Without this crisis we might have floated happily along on an illusory tide of cheap energy until it was too late to do anything about it.

The plan of action up to this point has been to reduce our dependence on foreign oil as much and as soon as possible. However, the strategies for accomplishing these goals are widely divergent. On the one hand, the oil industry and the President are favoring decontrolling the price of oil. In fact, the oil industry suggests that further price regulation (as opposed to decontrol of prices) will result in a decline in exploration and development due to problems with financing.

For example, William Slick, Jr., in his testimony before the Senate Committee on Finance on July 16, 1975 stated that the most critical factor in the area of developing resources is "the ability of the domestic energy producers in general and petroleum companies in particular to generate adequate capital to finance the very large development costs." [Slick-75]

On the other hand, many people feel that the results of decontrolling the price of domestic oil will be disastrous for the country as a whole. Two separate analyses showing the predicted results of allowing the decontrol of the price of domestic oil as compared to a case assuming existing controls (prior to August 31, 1975) are presented in Table 9.1-1.

The differences in the analyses, according to the supporters of the second analysis which was based on a Data Resources Incorporated model, are largely the result of the assumptions made in Analysis 1:

- No OPEC price increase on the cost of imported oil;

- Little or no increase in the price of coal or natural gas as a result of domestic crude oil price increases;

- Enactment of a windfall profits tax -- one that has not been spelled out; and

- Rebate to consumers to offset adverse effects of decontrol. The capital required for rebates will be produced by windfall profits tax.

Many proposals for controlling oil prices have been voiced in opposition to decontrol. However, any serious consideration of price control must be accompanied by some measures to counteract the obvious result -- decreasing prices would naturally lead to increased demand.

A list of the types of actions that might be proposed to combat this natural increase in consumption resulting from reduced prices (Action 1) follows:

Action 1

- Establish price ceilings of between \$7.50 and \$8.50 per barrel for all classifications of domestic oil production over the next 4 or 5 years. In the fourth year, ceilings would begin to increase at a rate of 8 percent per year.

TABLE 9.1-1. ANALYSES OF DECONTROL OF DOMESTIC OLD OIL

	<u>1975:4</u>	<u>1975:2</u>	<u>1976:4</u>	<u>1977:2</u>	<u>1977:4</u>
Consumer Price Index %					
Analysis 1	+0.08	+0.18	+0.35	+0.57	N.S.
Analysis 2	+0.18	+0.46	+0.90	+1.47	+2.06
Wholesale Price Index %					
Analysis 1	+0.03	+0.46	+0.97	+1.53	N.S.
Analysis 2	+0.74	+1.73	+3.09	+4.61	+6.13
Real GNP (billions \$ '58)					
Analysis 1	-0.2	-0.5	-2.2	-4.7	N.S.
Analysis 2	-0.6	-2.6	-8.3	-17.1	-26.0
Number of Unemployed (thousands)					
Analysis 1	0	0	0	+100	N.S.
Analysis 2	0	+100	+200	+500	+800
Housing Starts (thousands units)					
Analysis 1	-1	-15	-53	-89	N.S.
Analysis 2	-4	-51	-177	-273	-268
Automobile Sales (thousands units)					
Analysis 1	0	0	-100	-200	N.S.
Analysis 2	0	-100	-400	-800	-1000

N.S. -- Not submitted

Action 2

Restrict gasoline demand to 1973-74 levels for the next three years.

Action 3

Impose mandatory fuel efficiency requirements on new automobiles as follows:

<u>Model Year</u>	<u>MPG</u>
1978	18.5
1979	19.5
1980	20.5
1985	28.0

Action 4

Establish energy efficiency improvement targets for the 2000 largest industrial consumers as follows:

<u>Date</u>	<u>Improvement (compared to 1972)</u>
Jan. 1, 1978	15%
Jan. 1, 1981	20%

Action 5

Develop regulatory programs to make appliances and other consumer products more efficient, through mandatory testing, labeling, and possibly through the application of energy efficiency performance standards.

Action 6

Establish programs to make better use of coal, such as:

Guaranteed loan program to assist small coal operators in opening new underground low sulphur mines;

Encourage switchover from petroleum to coal;

Prohibit use of petroleum products in some cases.

The systems approach can be a valuable tool with which to assess such a list of actions (Figure 9.1-1). In fact, the major emphasis of this program has been the application of the systems approach and technology assessment to the study of large problems -- in this case conservation. Because of the interest in displaying the methodology for studying interactions within and between the various sectors of the economy, this set of actions is an appropriate example with which to work.

TABLE 9.1-2. ANALYSIS OF PROPOSED SET OF ACTIONS  
(Based on DRI Model)

	<u>1975:4</u>	<u>1976:2</u>	<u>1976:4</u>	<u>1977:2</u>	<u>1977:4</u>
Consumer Price Index %	-0.19	-0.39	-0.54	-0.62	-0.62
Wholesale Price Index %	-0.77	-1.47	-1.65	-1.65	-1.58
Real GNP (billions \$ '58)	+0.6	+2.2	+5.0	+7.9	+8.9
Number of Unemployed (thousands)	0	-100	-100	-200	-300
Housing Starts (thousands units)	+8	+41	+78	+83	+28
Auto Sales (thousands units)	0	+100	+200	+300	+300

## 9.2 DISCUSSION OF ACTIONS

This section will discuss each action in the list individually with respect to requirements for implementation, obstacles to implementation, and possible benefits. Section 9.3 will consider the set of actions taken together.

### 9.2.1 OIL PRICING PROPOSAL -- ACTION 1

This action is to immediately lower the price of current uncontrolled domestic "new" oil from \$11.28 to an average of \$7.50 per barrel, and over a period of time raise the price of controlled domestic "old" oil from \$5.25 to \$7.50 a barrel. Certain high recovery cost oils would be priced at an average \$8.50 a barrel. In addition, an inflation and adjustment factor is included (see Figure I.1-1). Essential to the proposal is the satisfaction of two criteria:

- To increase domestic production

- To reduce the price of energy to the consumer

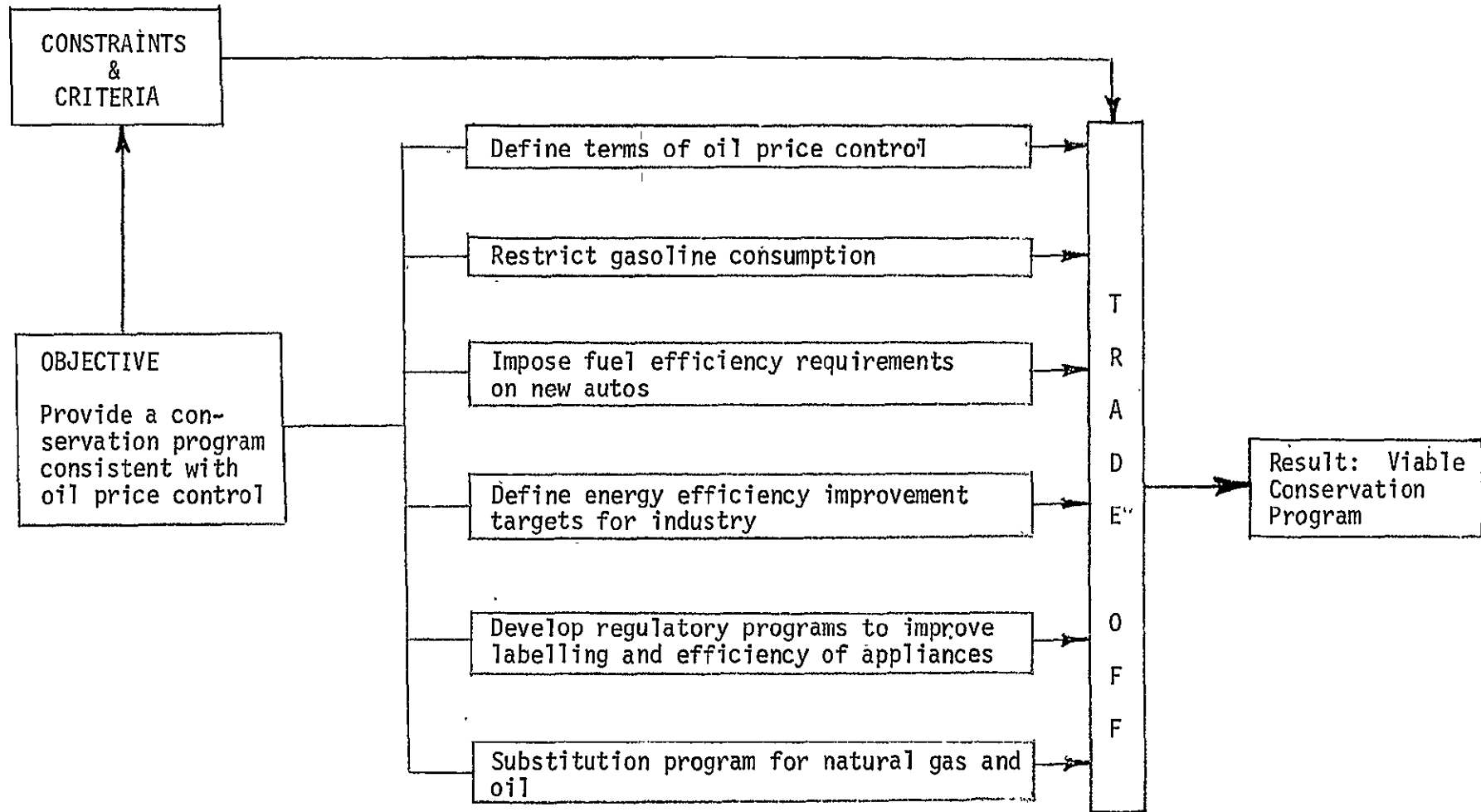
#### 9.2.1.1 PRESENT AND PROJECTED PRODUCTION

In July 1975 domestic production was approximately 66% or 5.6 million barrels a day "old" oil and 33% or 2.8 million barrels a day "new" oil. Interpolating F.E.A. projections to 1985 [PI-74-2] shows production based on \$7.50 a barrel increasing to 12.3 million barrels a day (under assumptions of policy in effect prior to 1973 except for price controls). At \$8.50 a barrel the production will be 13.1 million barrels a day by 1985 (see Table I.1-1). Forecasts by the National Petroleum Council and ten others range from 9.2 million to 15.5 million barrels a day by 1985 (see Table I.1-2). As much as 42% of the production could be from high production cost areas.

#### 9.2.1.2 JUSTIFICATION

Lowering the price of oil is not an energy conservation action. It does not encourage or require conservation, nor does it encourage or require substitution of less scarce fuels. It must be accompanied by counter-active measures, i.e., forcing use of coal, restricting gasoline consumption, to avoid excessive use of oil because of lower prices. The intent of lower prices is to encourage cash flow, employment and investment opportunities as reflected in the consumer price index, the wholesale price index and gross national product. It must be remembered that the combined domestic oil price today is only \$7.70 a barrel and that for a short time the cost of energy will be reduced. The immediate decrease of about 4 cents a gallon in the combined price of domestic oil will be erased in 6 years because of the planned increase in oil price. Oil producers will have a basis for planning in the predetermined rate of price adjustment. If oil imports do not increase,

FIGURE 9.1-1. INITIAL SYSTEMS DIAGRAM DISPLAYING THE RELATIONSHIP OF THE ACTIONS



The analysis presented in this chapter is an attempt to show interested persons how the systems approach should be applied to such a set of actions before it is introduced. In other words, before suggesting that such a set of actions be passed into law, an attempt should be made to identify and assess as many of the requirements of, alternatives to, and impacts of these actions as possible. The systems approach is a tool for accomplishing such an assessment.

The procedure for applying the systems analysis technique has been discussed in Sections 3.1 and 3.2. However, we might point out some of the steps in the procedure. One of the first duties of the group is to establish a set of constraints and criteria which the objective must satisfy.

The set of actions listed above are some of the requirements that could be envisioned as necessary to satisfy the objective, which is to provide a conservation program consistent with oil price control that will satisfy a list of constraints and criteria that must be identified. A partial listing of constraints and criteria applicable to this objective and its requirements might include:

Restoration of a healthy economy with full employment, reduced inflation and increased output and productivity in a short period of time;

Prevention of steep increases in the price of all energy and the pervasive economic adversities which such increases surely would entail;

Management of energy supply in the near term so as to reduce import dependence steadily and surely, consistent with rapid economic recovery, while providing standby protections against sudden supply curtailments;

Improvement of our balance of payments and achievement of national energy sufficiency in a timely and reliable way.

At this point each of the actions needs to be examined in detail -- establishing the requirements and impacts of each. Then, the group of actions should be assessed "in toto" since many of the impacts may not be obvious if the action is assessed in isolation.

Table 9.1-2 shows an analysis of this set of actions versus the current controls (prior to August 31, 1975) provided by Data Resources Incorporated. This data can be compared with that resulting from de-control as presented in Table 9.1-1.

The fact that the data presented by the DRI analysis of this set of actions is favorable is encouraging. However, the group felt the additional study, preferably in the form of a systems approach, is needed in order to identify and assess the impact of these actions. A description and preliminary assessment of each of the actions is provided in Section 9.2.



this country's export goods may enjoy a price advantage for some time in the world market. This would be an advantage also in the balance of payments.

### 9.2.1.3 REQUIREMENTS

By 1985, the price of domestic oil will be in the neighborhood of \$11 a barrel if 40% of production is high recovery cost oil, according to the action. In order to achieve projections of production by 1985 at \$11 a barrel, FEA projects a requirement of \$6390 million. In addition, there will be needed 131,696 rigmen, 5453 seismic crews, 3831 rigs, 656 platforms and 4,003,200 tons of steel (see Tables I.1-3 through I.1-6). In addition to the direct requirements for oil production, other areas affected are power requirements, refinery capacities, distribution systems, land and water use, manufacturing facilities, ecological balances, and lifestyles. [MEGASTAR-74] Besides the necessary money, manpower and materials to provide the production, implementation is dependent on how oil price changes affect price and demand for other fuels such as coal. It is also dependent on whether the price encourages exploration and production. The public must be convinced of the economic value of the action and be shown it is the best of the alternative actions.

### 9.2.2 RESTRICTION OF GASOLINE USE -- ACTION 2

During the period of the embargo in 1973 which was imposed on us by the OPEC countries, there was a short supply of most petroleum products. As a consequence, Congress passed the Emergency Petroleum Allocation Act in an attempt to ensure that all regions of the country were dealt with in an equitable manner by the oil industry. Allocation agencies, or state energy boards had authority to implement these regulations. The EPAA expiration date is August 31, 1975, so these agencies are still in existence even though the embargo has been lifted, and there are presently adequate supplies of fuel.

Because fuels are readily available, gasoline consumption is again increasing. This consumption would be heightened further if oil is regulated at lower prices, as Section 9.2.1. suggests. To prevent higher rates of gasoline consumption, it is desirable to consider an action that would keep gasoline consumption at a fixed level equal to that of 1974. To achieve this means that the allocation policies would have to be retained, i.e. the EPAA would have to be continued.

An auxiliary action that has a bearing on this is the possibility that regulations may be passed aimed at increased fuel economy for automobiles. This possibility will be discussed in Section 9.2.3. Large fuel savings can be achieved by increasing fuel efficiency, but the automobile manufacturers must have lead times to realize improvements. Since it is believed that quite significant economies can be achieved by 1978, it seems reasonable to continue allocation through that year. Further, allocation enforcement for three years may lead increasingly

to public resentment. For these reasons, it is proposed that the allocation period should begin January 1, 1976, and run through December 31, 1978. Since the President of the United States must execute the program, it is intended that he should be given extraordinary powers to carry out this action. If it is found that a fixed level of gasoline consumption can be easily met, it would be desirable to give the President power to achieve further reductions in end use if possible. It is proposed that he would be allowed to achieve another 4% reduction in gasoline usage if feasible under recognized socio-economic constraints. In the following discussion, the probable effects of this action will be studied.

#### 9.2.2.1 BACKGROUND

The historical growth trend for gasoline consumption over the past five years has averaged approximately 4% per year, and present consumption of gasoline by automobiles is about 4.5 million barrels per day. This represents about 9 quadrillion BTU's per year. It is useful to note that over 40 percent of automobile use is related to employment; 33 percent is used for social and recreational travel, and the rest occurs as a result of personal business.

#### 9.2.2.2 DIRECT RESULTS OF ACTION 2

Historical growth would produce a consumption of 10.5 quadrillion BTU's by the motoring public in 1978, an increase of about 750,000 bbl of gasoline per day. Using 1974 as a base year, and assuming this action to be in effect by January 1, 1976, the reduction from historical growth over the next three years would be -0.73, -1.12, -1.5 quads of BTU's. Since the President would be authorized to achieve up to a 4 percent reduction in comparison to the base year, a real reduction of 0.35 quads might occur.

The allocation program requirements would be minimal; yet, in 1978 alone would reduce projected foreign expenditure by four billion dollars per year. It is estimated that the allocation program would require manpower of only 500-1000 persons, at a direct cost per year of 5 to 10 million dollars, and the material requirements are minimal. Also, it appears that implementation of this action would be relatively easy. Most states already have energy boards and/or existing institutional structures for implementing the 1973 Emergency Petroleum Allocation Act. At this time, these structures are being paid for with federal and state monies.

#### 9.2.2.3 POSSIBLE IMPACTS

Consider the impact of this action of the public. With restricted gasoline supplies, service station managers will, in all likelihood,

area. However, there are potentially some serious consequences in the socio-economic area. In comparison with all eighteen near-term actions presented in Chapter 6.0, it ranks near the middle. Its ranking barely places it in the group which was suggested as those warranting further investigation and possible implementation.

### 9.2.3 MANDATORY AUTOMOBILE EFFICIENCY -- ACTION 3

This proposal is to set minimum average miles per gallon requirements of the yearly production of auto manufacturers as follows:

<u>MODEL YEAR</u>	<u>MPG</u>
1978	18.5
1979	19.5
1980	20.5
1985	28.0

Some possible impacts of this proposal are discussed in the remainder of this section.

#### Auto Manufacturers

Auto gas mileage averaged 14.0 mpg in 1974 [PMV-74,31]. Improvements in the gas mileage potential of an automobile can be bought about in several ways:

Transmission and drive train improvements.

Aerodynamic drag reduction.

Rolling resistance reduction.

Weight reduction.

Elimination or improvement of accessories.

Engine size reduction.

Engine improvements.

The auto manufacturers can attempt to meet the requirement by altering the production mix and/or considering the items in the above list.

According to [PMV-74,72], there is no evidence to suggest that improvements in fuel economy (to the extent discussed in that reference) of automobiles would have an effect on employment in the auto industry.

have to curtail their working hours. In an attempt to address this problem, gasoline retailers would be permitted to develop and carry out voluntary agreements to minimize motorist inconvenience. Closing of service stations on Sunday is to be avoided. However, in spite of this, it is likely that motorists in some areas will be again faced with lines and unavailable supplies at certain times.

If the public continues to average 1.4 passengers per vehicle in the urban area, and 2.4 passengers in the rural area, then by 1978, the number of passenger-miles per capita will be reduced by approximately 4.5%. If the President exercised his authority to reduce gasoline supply by another 4.0%, then the passenger-miles/capita will be reduced by 8.5%.

The easiest thing for the public to do, and yet retain historical growth in total passenger-miles, would be to save energy in the urban sector of their driving. Assuming no change in intercity driving, thus maintaining their ability to vacation, etc., carpooling could be formed to conserve fuel in the cities. It is estimated that an increase of 16% in numbers of passengers per vehicle would be required. If the President imposed an additional 4% cut in supply, this figure would change to 25%. For example, 30 to 40 percent of all urban vehicle miles would have to carry three persons to achieve these averages. This proposed life style change would produce minimal economic change, since those businesses catering to the recreational and entertainment demands would not be affected very much. However, this shift may be difficult to achieve.

Negative impacts are likely in the private sector, particularly affecting service stations, other service industries requiring transportation, businesses in the entertainment area, auto manufacturers, and the oil companies. Service stations are affected directly. Reduction of sales back to 1974 levels will reduce gross incomes unless prices increase. Since 70%-100% of their profits accrue from gasoline sales, reduced gross income may result in some unemployment. As there is no proposed restriction concerning gasoline retail prices, service stations will probably increase price. This will directly discriminate against lower income families. This is the case since these families are forced to spend a larger percent of their disposable income for transportation.

Generally, there will be a trend for families to purchase vehicles that achieve increased fuel economy. Those American auto manufacturers that do not have vehicles available with good fuel economy will probably stand to lose the most by this action. However, there are quite a number of foreign autos that do produce higher fuel economies; consequently, there may be an increasing trend for people to purchase these vehicles. This course would not help the overall U.S. balance of payments problem.

Finally, this specific conservation action was assessed using the methods discussed in Chapter 6. In comparison to other near term energy conservation actions, this action received a favorable rating. It directly helps to stabilize, if not improve, environmental quality, and it appears not to have serious consequences in the institutional

The same source estimates that investment costs would total \$1.0 billion by 1980 under Scenario B (see Table I.1-7), less for Scenarios A and C, and more for Scenario D. Since the proposal under consideration requires a greater increase in fuel economy than these scenarios, it seems logical to conclude that the required investment would be more. The auto manufacturers' competitive position in the world might be improved due to better gasoline economy.

[PI-74-11,75] projects average fuel efficiency for automobiles as 18.2 mpg in 1985 and 16.3 mpg in 1980, with oil at \$7/bbl, if there is only a mild incentive for auto manufacturers to improve economy and assuming 65 percent urban and 35 percent inter-city driving. Thus, the proposed 18.5 mpg in 1978 and 28.0 mpg in 1985 will not merely happen but will require significant effort on the part of the auto manufacturer. Figure I.1-2 from [PMV-74, 35] implies that the production mix will consist of a large percentage of small cars.

### Economic Impact on Consumers

There will be an attendant increase in first cost of an automobile in all three class sizes. The fuel and maintenance savings should more than offset this increase, however. For the cases examined in [PMV-74, 64-67], the improvements and costs are as shown in Table I.1-8 and I.1-9. From this information, an idea can be gotten on the effect of a 28 mpg average by 1985. An extensive analysis would be required to obtain more accurate numbers. With current gas mileage averaging about 14 mpg, it can be seen that a doubling of this figure to 28 mpg would permit the consumer to drive as much as ever without increasing his gasoline expenditures, even if the price of gasoline goes to as high as \$1.00 per gallon.

### Safety

One means the auto manufacturers will use to increase gas mileage is to manufacture smaller cars. Historically, small cars have been more dangerous than large ones in that occupants have been more likely to be killed or receive serious injury in accidents. Of course, if the percentage of small cars increases, then accidents between two cars would be more likely to involve two small cars rather than one small car and one large car, possibly reducing the danger of small cars. Further work needs to be done in this area to assess the impact of a larger percentage of small cars.

### The Economy

The initial price of cars would likely increase as a result of the gas mileage requirements specified in Action 3 because of technological improvements made necessary, and possibly because of the use of lighter and more expensive materials.

14 It is estimated in [PMV-74,71] that little effect on the consumer price index would occur as a result of an increase of 5-10% in the initial real price of new cars. This same reference estimates that \$400 (1974 dollars) would be added to the selling price of new cars by 1980 for a 40% economy improvement (19.6 mpg) and \$200 for a 30% economy improvement (18.2 mpg).

The balance of trade situation would be improved due to reduction in U. S. oil imports. Table I.1-10 gives estimates of the effect of the scenarios examined in that reference on oil imports. Savings should be more for Action 3.

#### 9.2.4 INDUSTRIAL EFFICIENCY IMPROVEMENT -- ACTION 4

Approximately 40% of all energy consumed in the United States is used by industry. Of this amount, approximately 70% ( $9 \times 10^6$  barrels/day) is consumed in manufacturing, and over 80% of the latter amount is used by the 2,000 largest energy consuming manufacturers.

Studies by the FEA have indicated (a) that very substantial savings of energy consumption per unit of product can be achieved by most industrial firms and (b) that over 27% improvement in energy efficiency per unit of output could be achieved by 1990 in six energy-intensive primary goods industries. The six most energy intensive industries are discussed in Appendix E.

Action 4 of the list of proposed actions assumes that these industries could accomplish a voluntary 20% reduction in energy consumption by 1985. The program would be voluntary since many people [PRE-74] feel that rising fuel cost will be sufficient incentive for industry to reduce consumption. In fact, many companies have already indicated that such percentages are fully within their capability. This may be an understatement of their potential in view of the fact that several industries have already reduced their energy consumption by more than 7.5% by simply implementing non-capital intensive good housekeeping measures. The FEA estimates that approximately  $2 \times 10^6$  barrels of oil equivalents/day (4.2 quad/year) can be saved if the 2000 largest energy consuming manufacturers improve their energy efficiency by 20% by 1981.

Although this reduction in consumption is believed to be well within the capability of most manufacturers, it is the general consensus that such savings can be attained only if the top management officials of each firm work diligently to achieve the objective of improving each firm's energy efficiency.

Since most of the non-capital intensive, good housekeeping type conservation measures have already been implemented in attaining the approximately 7.5% savings discussed above, the remaining reduction in consumption would require a capital commitment of varying degrees.

Since capital expenditures required for conservation actions will have to compete with other industrial programs requiring large capital investments, the potential for reduction in consumption may not be realized. For example, mandated environmental improvement program will require sizeable capital investments which will not be available for other projects.

Some of the conservation actions discussed in Section E.5 require large capital investments while others may have smaller potential savings but require less capital expenditure. For example, the capital estimated by Shell to save about 6% of their total consumption or approximately  $6.3 \times 10^{12}$  BTUs would be about \$10 million (Section E.5.4.2). Since Shell comprises only about 8% of the total U. S. refining capacity, somewhere in the neighborhood of \$100-\$150 million would be required for implementing these types of conservation measures in the refining industry alone, and the savings would amount to around 0.08 quads (see E.5.4.2). However, the payback period for these measures is estimated to be less than 2 years (this is a constraint apparently imposed upon any conservation action by most industries).

In fact, many studies of furnace insulation, combustion control, burner positioning, and similar capital improvements in heat-treating furnaces have been conducted. Industrial experts estimated in 1974 that applying insulation to all the uninsulated skid rail systems in the U. S. would result in a total fuel savings of approximately  $3 \times 10^4$  barrels of oil per day (0.08 quads/year). The economic justification for furnace rail insulation (Table 9.2.4-1) revealed that an expenditure of approximately \$100,000 an installation could save approximately \$234,000 worth of natural gas per year [SCI-74, 265].

As discussed in Section E.5.3, a large part of the heat of combustion of the fuel used in high temperature industrial furnaces is lost in the exhaust. In fact, in many furnaces, 50% or more of the energy used goes up the chimney. Approximately 11% of the total fuel consumption in the U. S. is used for direct heating operations in industry and it appears possible that as much as 30% of the fuel in certain direct heating operations can be saved through the use of devices similar to the one depicted in Figure 9.2.4-1.

According to the April 1974 issue of Science, "As for the use of such devices on radiant tubes alone, there are approximately 900,000 radiant tubes in heat-treating furnaces in U. S. plants, and very few of them are equipped with heat recuperators. Heat recuperators are being introduced to the market now for this purpose. Industrial estimates indicate that each recuperator can save fuel equivalent of 1/2 barrel of oil per day. Recuperators cost \$1,000 to \$1,500 per unit. The total potential (equivalent) fuel saving for all the radiant tubes in operation today is of the order of 450,000 barrels of oil per day. Furthermore, a device costing \$1,000 to \$1,500, which will eliminate the need for 1/2 barrel of oil per day (equivalent) is economically rather attractive now." [SCI-74, 266]

9-16

TABLE 9.2.4-1  
ECONOMIC JUSTIFICATION  
FOR  
FURNACE RAIL INSULATION [SCI-74, 266]

Item	Annual amount (dollars)
Capital cost	100,000
<u>Operating cost analysis</u>	
Maintenance, 5 percent of capital cost	5,000
Taxes and insurance, 2 percent of capital cost	2,000
Interest, 4.5 percent of capital cost	4,500
Depreciation in 1 year	100,000
Total annual operating cost	<u>111,500</u>
<u>Economic benefit of fuel use reduction</u>	
Annual fuel cost reduction*	243,734
Annual cost	111,500
Annual benefit	132,234

\* Calculated on the basis of 40.3 thousand cubic feet per hour, for 8400 hours per year, at \$0.72 per thousand cubic feet.

This table shows the costs and benefits of insulating water-cooled skids in a reheat furnace. The furnace capacity is 160 tons per day; insulation reduces heat input by 40.3 million BTU per hour. Fuel, at \$0.72 per thousand cubic feet, is reduced by 40.3 thousand cubic feet per hour.

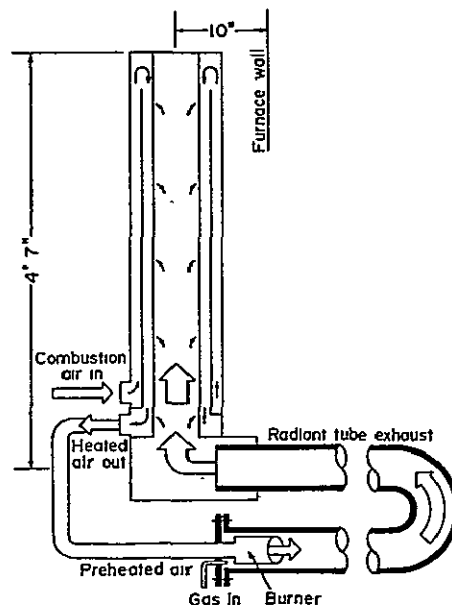


FIGURE 9.2.4-1. A heat recuperator suitable for recapturing stack gas heat from a radiant fired tube and using it to preheat combustion air. [SCI-74.266]



Wider application of combustion control systems appears to be an economically attractive answer for increasing combustion efficiency as discussed in Section E.5.1. Estimates from 5-10 up to 30% reduction in fuel consumption have been recorded. [SCI-74, 267] Thus, the use of computer controls in the operation of large thermal processing plants appear to be an extremely attractive way to save fuel and reduce costs. For example, the use of on-line computer controls to execute a carefully devised program of operation for steel reheating in one European steel plant resulted in a 25% reduction in fuel consumption per ton of production, and was accompanied by a 12% increase in the plant's rate of production.

In the area of longer range possibilities the development of improved plant equipment is under investigation. An example of such equipment is the heat pipe vacuum furnaces. [SCI-74, 268]

Another method for improving industrial fuel efficiency, is combining the generation of electricity and process steam production and is discussed in some detail in Section E.5.2. One of the first questions to be answered is, "Is it actually technically feasible or economically attractive to build thermally integrated steam raising power generation plants?" The idea is neither new nor economically uncertain. In fact, during the 1920's and early 1930's, several major paper companies proved that cogeneration is a very profitable way to generate electricity. The program was so successful, in fact, that during the 1930's the Department of Justice took an interest in the matter. In a series of court suits the paper companies were required to decide whether they were in the paper business or the electric power business, and most opted for the paper business, leaving power generation behind [SCI-74, 268].

Thus, the technical feasibility and economic attractiveness of thermally integrated steam raising and power generation has long been established. However, the problems in implementing the measure are many. For example, not only industries, but also the utilities would have to be convinced of the value of such an action. The number of industries capable of undertaking such a venture would have to be determined because industries that are large enough to tackle the problem economically may be limited in number and those capable of such an undertaking may be reluctant to do so due to fuel supply problems and the management and operation necessary in this new area are largely unfamiliar to them. Will there be sufficient manpower available? At the same time utilities will probably be reluctant to accept the idea of purchasing electricity from an industry to sell to their customers. Although this intermediary role for utilities appears to be logical, there would probably be considerable opposition. The essential problems in trying to adopt such a measure involves finding ways to do so without abridging other requirements of society, such as preserving open competition of industry.

Much the same can be said for another alternative measure that would again be aimed at increasing the efficiency in power generation: the location of industry around a power plant in order to utilize the waste steam produced. Obviously, this is an old idea but one that has not been encouraged in the past. In the future, perhaps the government might provide a clearing house for information concerning the industrial operations. Some coordination of these planned expansions might be fruitful in these areas. Once again, siting industry (and the accompanying employees) near a generating plant has obvious obstacles that must be considered and dealt with prior to the implementation of such a plan. For example, one of the requirements for siting a nuclear power plant in the past has been to locate the plant in an area of low population density. This type of planning for the utilization of waste heat would have to include an evaluation of the possibility that the population density around the plant would be great. Along this line, the use of waste steam in such homes might be investigated as a possible positive side effect.

As can be seen from this discussion, some of the actions that have been proposed for industry are far reaching in their impacts. These impacts must be evaluated and dealt with before the action is implemented.

The availability of materials and equipment for various conservation actions may be an area of concern. For example, suppose all industries installed air preheaters. Is there sufficient manufacturing capability to furnish these air preheaters without taxing the industry or causing them to overbuild to supply this item? On the other hand, suppose the air preheater manufacturers could not supply the necessary air preheaters as quickly as needed and refused to tool up to provide them. In this case, a reduction in consumption of energy would be dependent on how quickly the air preheaters could be manufactured and then installed. Since the potential savings attributable to the installation of air preheaters is significant, this conservation action should be subjected to a systematic study and evaluation. Identifying impacts prior to implementation gives one the opportunity to provide an alternate solution or to deal with the expected impact in a planned manner.

### 9.2.5 ENERGY LABELING AND EFFICIENCY STANDARDS FOR CONSUMER PRODUCTS OTHER THAN AUTOMOBILES -- ACTION 5

Energy used in the residential sector accounts for 19 percent of total energy consumed in this country. In 1970 95% of this point of use energy consumption was in for the following end uses: space heating (68%), water heating (15%), cooking (5%), refrigeration (3%), clothes drying (2%) and air conditioning (2%). Thus this area offers high potential for energy savings and considerable attention has been focused on increasing the efficiencies of appliances to effect these savings.

Action 5 of the proposed actions calls for the achievement of a 25% reduction in energy usage of new major energy consuming consumer products relative to their output by 1980 as compared to their usage in 1974. The labeling requirements may be made applicable to the following types of consumer products:

Room and central air-conditioners

Refrigerators

Freezers

Dishwashers

Clothes dryers

Kitchen ranges and ovens

Water heaters

Home heating equipment, including furnaces

Television sets

Clothes washers

Humidifiers and dehumidifiers

Any other type of consumer product, if the average annual per household energy use by product in such type exceeds 100 kilowatt hours per year.

Average annual per household energy use of a consumer product of a particular type is defined as aggregate energy use (KWh or BTU) of consumer products of that type which are used by households, divided by the number of households in which products of that type are used.

The action which is to be taken is to establish a program of energy labeling and test procedures. The energy labeling is designed to (1) assist purchasers in determining which consumer products have low energy use or high efficiency, (2) encourage manufactures to sell products which have low energy use or high energy efficiency. The purpose of the test procedures is to establish energy use or relative energy efficiency under conditions approximating actual use. The first priority of the proposal, at least in the first few years, is to be energy labeling. It was hoped that voluntary efforts of the manufacturers and better consumer information would be sufficient to attain the energy conservation goal.

Separate energy efficiency improvement targets for each individual energy consuming product are to be set. The level of the energy improvement target for each type of consumer product is to be established based on the degree of improvement that is feasible for that type of product, and the amount of improvement necessary to meet the overall goal of 25%. If any type of product does not attain its goal, an energy efficiency standard will be established for that type of product. Energy efficiency standards may be prescribed only after labeling requirements have been in effect for at least 18 months. The criteria for setting energy efficiency standards are: (1) that it is technologically and economically feasible to improve energy efficiency or energy use of consumer products of such type, (2) that the labeling requirement is not sufficient to induce manufacturers to produce, or consumers to buy, consumer products of such type which achieve the maximum energy efficiency or improvement of energy use which is technologically and economically feasible, and (3) that the benefits of reduced energy consumption and life cycle costs outweigh first cost increases, lessening of utility, and negative effects on competition.

The proposed action should contain a statement as to the amount of energy savings to be expected in 1980 if the goal of 25% aggregate increase in efficiency of the named consumer products is attained. Thus it appears that an analysis should be undertaken to weigh expected benefits against expected costs to industry and consumer. Also it seems that an attempt should be made to determine if this action would indeed result in a net energy savings or if the requirements for its attainment could be satisfied in light of all of the other actions, with attendant requirements, that were proposed. These points are addressed in the following paragraphs.

The 25% increase in aggregate consumer product efficiency was an extension of the President's request for a 25% increase in consumer product efficiency. This extension was based on the results of an FEA report which cited potential energy savings, from efficiency and energy use improvements of consumer products, of 29%. This report, however excluded central air conditioners and home furnaces from the analysis and used 1972 energy consumption data as a baseline. The proposed action

includes central air conditioners and furnaces in its list of consumer products as part of the aggregation that is to achieve 25% energy efficiency improvement, and uses the base year 1974. As space heating accounts for 68% of the energy use in the residential sector, it would have a pronounced effect on any aggregate energy efficiency goal. This should be considered in setting the goal. Also, Project Independence projected that the unit consumption of at least some of the consumer products listed would decrease between 1972 and 1974 [PI-74-5], which should also be considered in setting the goal and base year.

A comparison between savings to be realized and the expense to be incurred by industry in reaching the goal should be included in the proposed action. The consumer will ultimately pay the bill for any expense incurred in product modification (as he did in the case of pollution controls on automobiles) so that the neglect of a comparison between expected savings and costs would be a neglect of a potential impact on the consumer.

The efficiency improvement targets are to take into consideration the feasibility of goal attainment for each type of consumer product. A systematic analysis should be undertaken to determine a priori if the feasibility of attainment of the 25% aggregate efficiency improvement is realistic considering all of the actions which are included in the National Energy Conservation Proposal. The goal should be set after a determination is made as to its feasibility with regard to requirements to attain this goal. Provision is made for the setting of energy efficiency standards if it is determined that it is technologically and economically feasible for a particular type of product to reach its goal and if the attainment of the goal will result in a lower life cycle cost to the consumer weighed against lessened utility or negative effects on competition. This determination should be made before setting the goal and thus the potential hardships that may impact consumers and industry in the period while industry strives for goal attainment. The consumer product industry should be consulted when setting the efficiency goal to be as sure as possible that it is realistic and that there is a reasonable possibility of attaining it. This is especially true of a voluntary program which depends, for its success, on the cooperation of industry. If industry feels they are being asked to attain an impossible goal which has not been well thought out or are being unjustifiably pressured, the possibility of attaining the goal will be lessened. It may be that the 25% goal is an unrealistic one. Some major appliance manufacturers have stated reservations as to the possibility of the attainment of even the 20% goal suggested by President Ford. As a case in point, the General Electric Company major appliance group addressed the question of attaining a 20% average reduction in the energy usage of new home appliances by 1980 as compared to new home appliances built in 1972 (President Ford's January 15, 1975, message to Congress). The following is a quote from [GE-75-1]:

"It was generally agreed that an average 20 percent reduction in the energy consumption of appliances in the time span from 1972 to 1980 was a very ambitious goal that will tax both the technical and economic resources of the appliance industry. In order to attain an average 20% reduction, the goals for individual appliances have been set both above and below 20 percent. For example:" (See Table 9.2.5-1 [GE-75-1])

This listing does not include two of the biggest energy consumers; central air conditioners and space heating equipment. They make the point that increasing the efficiency of central air conditioners from a current EER of 7.4 to 10 would entail a very large increase in the cost over units today. They made no comment on the question of space heating equipment except with regard to heat pumps. The point here is that one of the major manufacturers of energy consuming consumer products has testified to the fact that the attainment of a 20% average increase in consumer products efficiency would be a "very ambitious goal" whereas the proposed action suggests a 25% improvement. It is not the intention to sympathize with the consumer product manufacturers, but to emphasize that a feasibility analysis should be done a priori, taking into consideration the other actions which would be enacted concurrently as part of a national energy conservation proposal. That is, a systems approach or Technology Assessment should be used to assess the feasibility of the entire proposal including all the actions. Part of any analysis should be a study of the net energetics of each of the actions. Will the action truly lead to a net energy savings after the additional energy embodied in any new materials or manufacturing processes necessary to effect the efficiency improvement are subtracted from the operating energy savings realized by using the new efficient product rather than the old 1974 product? This net energy savings is that which should be compared to the financial costs of attaining it when making a cost benefit study.

There are other impacts which should be assessed before proposing this action, such as the impact that its' enactment would have on the building industry. Any increase in the price of consumer products would certainly affect the selling prices for new homes with the space conditioning equipment adding the largest increment. Utilities should also be considered for their revenues may drop to the extent that their rates would have to be raised. This would mean that consumers would ultimately pay more for his monthly bill for less consumption. This was the situation that occurred in some regions during the winter of 1974 when consumers curtailed demand. Consumer product manufacturers must also be considered as they must be able to balance any increased costs with increased revenues. Lost revenues would have to be passed on to the consumer in the form of higher prices. If their sales decrease it may result in unemployment. There is also the problem of disposing of, rather than reselling, second-hand inefficient appliances. This leads to the point of whether energy saving appliances will sell in light of their increased price. The public must be educated to the concept of life-cycle costing. One solution might be to put all savings in terms of dollars rather than energy units. Before proposing any action which is designed to save energy, an analysis must be done to assess all the implications and impacts that go along with it.

TABLE 9.2.5-1  
APPLIANCE ENERGY, USE REDUCTION GOALS [GE-75-1]

Appliance	1980 Goal
Refrigerators	30%
Ranges	
Gas	30%
Electric	10%
Room Air Conditioners	22%
Dryers	
Gas	12%
Electric	6%
Water Heaters	
Gas	25%
Electric	9%
Freezers	25%
Television	
Black and white	48%
Color	42%

### 9.2.6 INCREASED USE OF COAL -- ACTION 6

Action 6 provides for the utilization of coal in all power plants with existing coal facilities and for the conversion of sufficient natural gas fired plants to alleviate natural gas shortages. The FEA has reviewed the status of existing power plants and has found 155 boilers at 79 stations with a combined capacity of 25,000 MW which could be converted to coal without major modification. [Power-75,33]. In addition it is proposed that a sufficient number of gas fired plants are converted to oil to overcome a deficit of 1.1 trillion cubic feet/year of natural gas [HR. 7014 Hearings-75,1107].

These combined actions would reduce natural gas requirements in existing power plants from  $3.4 \times 10^6$  to  $2.3 \text{ MMCF/year}$ , oil requirements from  $527 \times 10^6$  to  $505.9 \times 10^6 \text{ bbl/year}$  and increase coal needs from  $389.3 \times 10^6$  to  $427.3 \times 10^6 \text{ tons/year}$ . At \$11/bbl for oil the direct improvement in balance of payments would be \$233 million/year. One problem is that of obtaining sufficient coal supplies. Both power plant construction and mine development require significant lead times so that future coal requirements and availability may be projected at least three years with a relatively high degree of accuracy. The scheduled startup of new fossil fuel-fired plants [EW-75,58] and the opening of new mines [Murphy-75] show no expected surplus of coal by 1977. However it was found that an additional  $31.4 \times 10^6 \text{ tons/year}$  might be produced by 1977 if an aggressive development program were undertaken today. While this is still somewhat short of the  $38 \times 10^6 \text{ tons}$  required for all FEA conversions it does indicate that the conversion process could be completed before 1980. In the interim period it may prove advantageous to import coal and to alleviate any transient deficit.

Using a value of \$11/bbl for oil as compared to \$26/ton for coal, it is found that conversion of the FEA designated plants to coal would reduce annual fuel costs from \$1.77 billion to \$.988 billion. This is an annual improvement in the balance of payments of \$.783 billion, even if all coal is imported. Conversion costs are estimated at \$11.9 billion under present state environmental implementation plans but would drop to \$0.6 billion (1980 dollars) if standards were relaxed to the primary and secondary federal ambient standards. [Allen-75] It is apparent that the economic feasibility of such a conversion is directly related to the environmental standards. Many of the utilities and coal producers advocate a review of environmental standards with a trade-off between the national needs of environmental conditions and energy needs.

Retrofitting of boilers to utilize coal in plants not designed for coal has previously been proposed. The costs of such a retrofit program has been estimated at \$26 billion (1980 dollars) exclusive of capital required to meet air pollution control requirements or of capital outlays by supporting railroad, etc. [Allen-75] As noted from Table I.2-2, sufficient coal supplies are simply not available



to accomplish such a conversion prior to 1978. It is clear that any retrofit program will be hampered by the rate at which additional mines can be developed and should be delayed until coal production surpluses can be attained. Note that the cost of retrofit is of the same order of magnitude as the cost of the coal gasification programs in Appendix D. Both programs provide about 3 quads of additional pipeline gas and both cost on the order of \$30 billion. However, gasification plants would be new facilities with a 40 year lifetime, whereas retrofitting of old natural gas plants would provide significantly shorter service.

An additional area of concern is conversion to coal in transportation. Rail facilities, particularly in the Northeast, have deteriorated over the past several years and will require upgrading. Today there is both a shortage of hopper cars and coal barges so that potentially significant problems may occur in transport. The problem will be accentuated by development of the low sulfur coal areas of the Northern Great Plains. While rail lines are generally in good repair in this region, the distance travelled to major population areas is enormous. This may be seen in Figure I.2-1. Barge transport is generally much cheaper than rail, but no waterways of sufficient depth are found in the area. Generally, it is recognized that rail transport will be required at least to the Mississippi River. From there, coal may move east either up the Ohio River or down through the Gulf. Transportation by rail provides a significant side benefit of providing substantial revenues to rail systems. In fact, coal transport constitutes the railroads' single most important commodity class. Thus, conversion to coal serves to stabilize rail revenues.

### 9.3 INPUT-OUTPUT ANALYSIS OF NATIONAL ENERGY CONSERVATION

Let S refer to actions relating to substitution of coal for oil and gas. Following the discussion of proposed actions presented in Section 9.2, substitution refers to a 100% switch away from gas and a 50% switch away from oil to coal in generating electricity. Let E refer to actions directly impacting on industrial energy efficiency. The major action is a proposed 20% improvement in industrial energy use. The time frame is 1985. Let C refer to actions which impact on the consumption sector. Included in this category would be mandated improvements in miles per gallon and home appliance operation efficiency.

The assessments of actions in sets S and E were made using the ECASTAR energy input-output model. Actions in set C were evaluated outside the context of the I-O model. The years 1967, 1980, and 1985 were selected in order to trace what the secondary impacts were likely to be. Each time period is analyzed separately.

#### 9.3.1 1967-THE BASE

Energy source requirements for 1967 are presented in Table 9.3.1-1.

TABLE 9.3.1-1

COMPARISON OF ENERGY REQUIREMENTS  
UNDER VARIOUS CONSERVATION ACTIONS  
1967

$\times 10^{15}$  BTU's

Action(s)		COAL	REFINED PETROLEUM	NATURAL GAS	TOTAL
Base	(1)	14.8	26.1	18.45	59.35
S	(2)	18.1	25.6	15.65	59.35
S and E	(3)	15.7	20.8	15.30	51.80
E	(4)	12.5	22.0	17.9	52.40

- (1) Base Case-Bureau of Labor Statistics
- (2) Substitution Actions (Coal for oil and gas as discussed in section 9.2)
- (3) Substitution and industrial efficiency improvements (as discussed in 9.2)
- (4) Industrial efficiency improvements only.

Implementing only the industrial efficiency standards would have produced an 11% reduction in overall energy use in 1967. The indirect impacts associated with efficiency improvements are far less than for substitution. The major drawback to a policy aimed only at increasing efficiency is that it may not reduce the energy requirement of oil and natural gas enough to curtail imports. This presents serious problems in the 1985 case -- where estimated natural gas requirements are over 40 quads.

### 9.3.2 1980 PROJECTIONS

Estimated energy demand by source for 1980 is given in Table 9.3.2-1. The 1980 base case was based on the BLS projected estimates for 1980 and 1985. This case is very much like a historical growth extrapolation. While historical growth is unlikely to pace the future, it is nevertheless instructive to compare the effectiveness of conservation actions to this standard.

By 1980, if the substitution strategy had been followed, the additional requirement in coal production would be almost 10 quads. If both the substitution and efficiency strategies were followed, almost an additional 6 quads of coal would be needed.

The indirect requirements in terms of quads needed to produce the additional coal would be 2.4 quads for substitution only and 1.4 quads for both substitution and increased efficiency. Table 9.3.2-2 highlights the additional requirements which would be necessary to permit the substitution. Note that these projections are requirements above the 1980 projected output levels. A detailed analysis of each major industry's capacity to expand would be necessary to complement the assessment of substitution.

Those numbers should be compared relative to the projected growth of the input industries. Table 9.3.2-3 provides a perspective of what an additional 1% in growth implies. Employment estimates do not take productivity changes into consideration.

Table 9.3.2-4 presents energy requirements under the assumption natural gas demand is held constant at 1974 levels. Considerable quad savings can be brought about by accepting a 1.5% decrease in GNP relative to what it would have been for the 1980 base case. It has been pointed out in earlier chapters that a reduction in final demand will imply overall energy savings. Note, however, as final demand falls, so does GNP.

### 9.3-3 1985 PROJECTION

Tables 9.3.3-1, 9.3.3-2, and 9.3.3-3 summarize the energy and related input requirements for various cases in 1985. The S and E conservation program appears to save 11%, relative to the 1985 base case. However, to bring about the substitution, another 2.5 quads of indirect, imbedded energy would be required.

9-28

TABLE 9.3.2-1

COMPARISON OF ENERGY REQUIREMENTS  
UNDER VARIOUS CONSERVATION ACTIONS

		1980 x10 <sup>15</sup> BTU's		
Action(s)		COAL	REFINED PETROLEUM	NATURAL GAS
Base Case (1)		24.6	34.9	39.9
S (2)		34.0	37.86	27.5
S and E (3)		31.72	32.70	25.0
E (4)		24.17	33.45	32.56
				TOTAL
				99.4
				99.36
				89.4
				90.18

- (1) Base Case-Bureau of Labor Statistics  
 (2) Substitution Actions (Coal for oil and gas as discussed in section 9.2)  
 (3) Substitution and industrial efficiency improvements (as discussed in 9.2)  
 (4) Industrial efficiency improvements only.

TABLE 9.3.2-2

ADDITIONAL REQUIREMENTS ASSOCIATED  
WITH THE SUBSTITUTION STRATEGY  
1980

Industry group	Additional output growth required (%)	Additional labor required (10 <sup>3</sup> )
Primary metals	0.8	11.0
Water	1.0	0.6
Machinery	2.0	84.0
Transportation manufacturing	0.3	4.0
Transportation	2.3	92.0
Retail/wholesale trade	0.4	50.0
Chemicals and allied products	1.1	10.0

ORIGINAL PAGE IS  
OF POOR QUALITY

TABLE 9.3.2-3

PROJECTED OUTPUT GROWTH FOR SELECTED  
INDUSTRIES FROM 1967 to 1980

INDUSTRIES	1967 TOTAL OUTPUT (\$ x 10 <sup>9</sup> )	1980 TOTAL OUTPUT (\$x 10 <sup>9</sup> )	1967 EMPLOYMENT (x 10 <sup>3</sup> )	1980 EMPLOYMENT (x 10 <sup>3</sup> )
Primary metals	50.9	86.5	1350	2220
Water	2.8	4.0	46	59
Machinery	63.6	111.0	1390	4180
Transportation manufacturing	70.4	125.0	1950	3320
Transportation	46.8	75.6	2830	4060
Retail/wholesale trade	162.0	256.0	16150	25300
Chemicals	46.5	84.9	1001	1800

TABLE 9.3.2-4

COMPARISON OF ENERGY OUTPUT REQUIREMENTS  
UNDER VARIOUS CONSERVATION ACTIONS  
ASSUMING FINAL DEMAND FOR  
NATURAL GAS IS FIXED  
AT 1974 LEVELS

		$\times 10^{15}$ BTU's		
Action(s)		Refined Petroleum	Natural Gas	Total
Base	(1) 26.1	38.5	30.1	94.7
S	(2) 33.9	37.9	22.5	94.4
S and E	(3) 31.7	32.6	20.4	84.7
E	(4) 24.2	33.3	27.5	85.1

- (1) Base Case-Bureau of Labor Statistics
- (2) Substitution Actions (Coal for oil and gas as discussed in section 9.2)
- (3) Substitution and industrial efficiency improvements (as discussed in 9.2)
- (4) Industrial efficiency improvements only.

TABLE 9.3.3-1

COMPARISON OF ENERGY REQUIREMENTS  
UNDER VARIOUS CONSERVATION ACTIONS

		1985 $\times 10^{15}$ BTU's		
Action(s)		Refined Petroleum	Natural Gas	Total
Base core	(1) 29.0	49.0	44.0	122.0
S	(2) 41	48.3	33.0	122.3
S and E	(3) 37.1	44.0	31.0	112.1
E	(4) 28.6	46.2	41.7	116.5

- (1) Base Case, Bureau of Labor Statistics
- (2) Substitution action (coal for oil and gas as discussed in section 9.2)
- (3) Substitution and Industrial Efficiency Improvements (as discussed in 9.2)
- (4) Industrial Efficiency Improvements Only

TABLE 9.3.3-2  
 ADDITIONAL REQUIREMENTS ASSOCIATED  
 WITH THE SUBSTITUTION STRATEGY (1)  
 1985

Industry Group	Additional output growth required (%)	Additional labor required ( $\times 10^3$ )
Primary metals	1.8	14
Water	1.4	1
Machinery	3.2	1
Transportation Manufacturing	0.45	41
Transportation	3.5	99
Retail/wholesale trade	0.7	71
Chemicals	1.5	12

(1) Substitution Strategy is switching 100% away from natural gas and 50% away from oil as discussed in Section 9.2

TABLE 9.3.3-3  
 PROJECTED OUTPUT GROWTH FOR SELECTED  
 INDUSTRIES FROM 1980 to 1985 (1)

Industries	1980 Total Output (\$ $\times 10^9$ )	1985 Total Output (\$ $\times 10^9$ )	1980 Labor ( $\times 10^3$ )	1985 Labor ( $\times 10^3$ )
Primary Metals	86.5	104.2	2220	2760
Water	4.0	4.5	59	65
Machinery	111.0	136.1	4180	5100
Transportation Manufacturing	125.0	144.0	3320	3800
Transportation	75.6	90.0	4060	4800
Retail/wholesale trade	256.0	300.0	25300	29600
Chemicals	84.9	104.0	1800	2200

(1) From Bureau of Labor Statistics

If the proposed actions which directly impacted on industry had been implemented in 1967, overall industry energy savings would be approximately 12.5%. Note that industry includes mining, construction, manufacturing, and services. The direct impact of substitution is a shift in the source requirements. In 1967 over 3 additional quads of coal would have been needed. Substitution raises an interesting question. Was there the excess capacity to produce 3 more quads of coal? Would there have been sufficient quantities of inputs into coal mining -- water, steel, rail cars, employment? The magnitude of these secondary requirements determines how feasible the substitution is. Note also that since the ECSTAR model does not have a nuclear sector, some of the burden which falls on coal will be directed to alternative energy sources -- nuclear, for example.

The indirect impacts of substituting coal for oil and gas are substantial. In 1967 dollars, the substitution would have implied a billion dollar increase in coal production. To achieve this additional production almost 3/4 of a quad of additional energy would have to be used. Furthermore, the increased coal production would require:

primary metals output to increase by 2%

water output to increase by 1 1/2%

machinery output to increase by 1%

vehicle manufacturing (primarily rail) output to increase by 6%

transportation and warehousing output to increase by 3%

The implied indirect increases in manpower would be an additional:

45,000 for coal mining

27,000 for steel manufacturing

117,000 for transportation equipment

85,000 for transportation

While these estimates need to be qualified, given the aggregation inherent in the model, they nonetheless point out that major secondary impacts are likely to occur. These gains, moreover, are not offset by the decline in gas and oil allocated to electric utilities.

The direction and magnitude of the indirect impacts suggest that substitution may be more easily implemented when the economy is slack. Such substitution might well fuel an economic recovery. However, adopting substitution when the economy is rapidly moving towards full employment will necessarily increase competition for industry output. A tradeoff in a growing economy, between energy substitution and other areas of growth, could well alter patterns of investment and consumption for years to come.

Table 9.3.3-4 describes the energy requirements if the final demand for natural gas was held constant at its 1974 level. At best a 16% reduction relative to the 1985 base case can be achieved -- at a cost of 1% in terms of GNP growth from 1980 to 1985.

Extreme care should be used when assessing these numbers. First, the proposed actions were made to impact immediately in any one year. A gradual scheduled shift would help moderate the impacts. Secondly, all the feedbacks were not assessed via an iterative procedure. Reaction to prices and output constraints was not built into the model. Finally, other energy sources were not fully accounted for.

It does appear, however, that because of the recent economic slump and the reluctance to deregulate natural gas, conservation aimed at increasing efficiency may help reduce consumption to approximately 104 quads by 1985.

Actions contained in set C were considered in the 1985 case only. Table 9.3.3-5 presents rough estimates of the savings brought about by these actions.

#### 9.3.4 SUMMARY

The previous tables characterized estimates of the effectiveness of a set of actions in an economy moving along an historical growth curve. Included with these numbers were estimates of some of the subsidiary impacts. While it was recognized that much refinement in the model is required, the model nevertheless uncovered certain areas which deserve close monitoring -- among them production in the transportation, primary metals, and machinery industries. Simulating the model under various sets of assumptions is necessary in order to assess the sensitivity of the economy to certain impacts. Some variables which deserve attention are: energy industry capacity, steel output, prices, GNP growth, unemployment, and aggregate demand. Impacts which result from a change in government spending should also be analyzed. This is particularly important if the government plans to underwrite research and development and technology assessment in the energy area. For example, the decision itself to go electric using nuclear and coal as primary fuels implies a host of direct and indirect impacts that need to be taken into account.



TABLE 9.3.3-4

COMPARISON OF ENERGY REQUIREMENTS  
UNDER VARIOUS CONSERVATION ACTIONS  
ASSUMING DEMAND FOR NATURAL GAS  
FIXED AT THE 1974 LEVEL  
1984

9.33

$\times 10^{15}$ BTU's				
Action(s)	Coal	Refined Petroleum	Natural Gas	Total
Base <sup>(1)</sup>	33.2	48.9	32.9	115.2
S <sup>(2)</sup>	40.86	47.5	25.8	114.2
S and E <sup>(3)</sup>	38.0	41.0	23.2	102.2
E <sup>(4)</sup>	31.1	43.2	29.5	103.8

(1) Base Case Bureau of Labor Statistics

(2) Substitution action (coal for oil and gas as discussed in Section 9.2)

(3) Substitution and Industrial Efficiency Improvements as discussed in 9.2

(4) Industrial Efficiency Improvements Only

TABLE 9.3.3-5

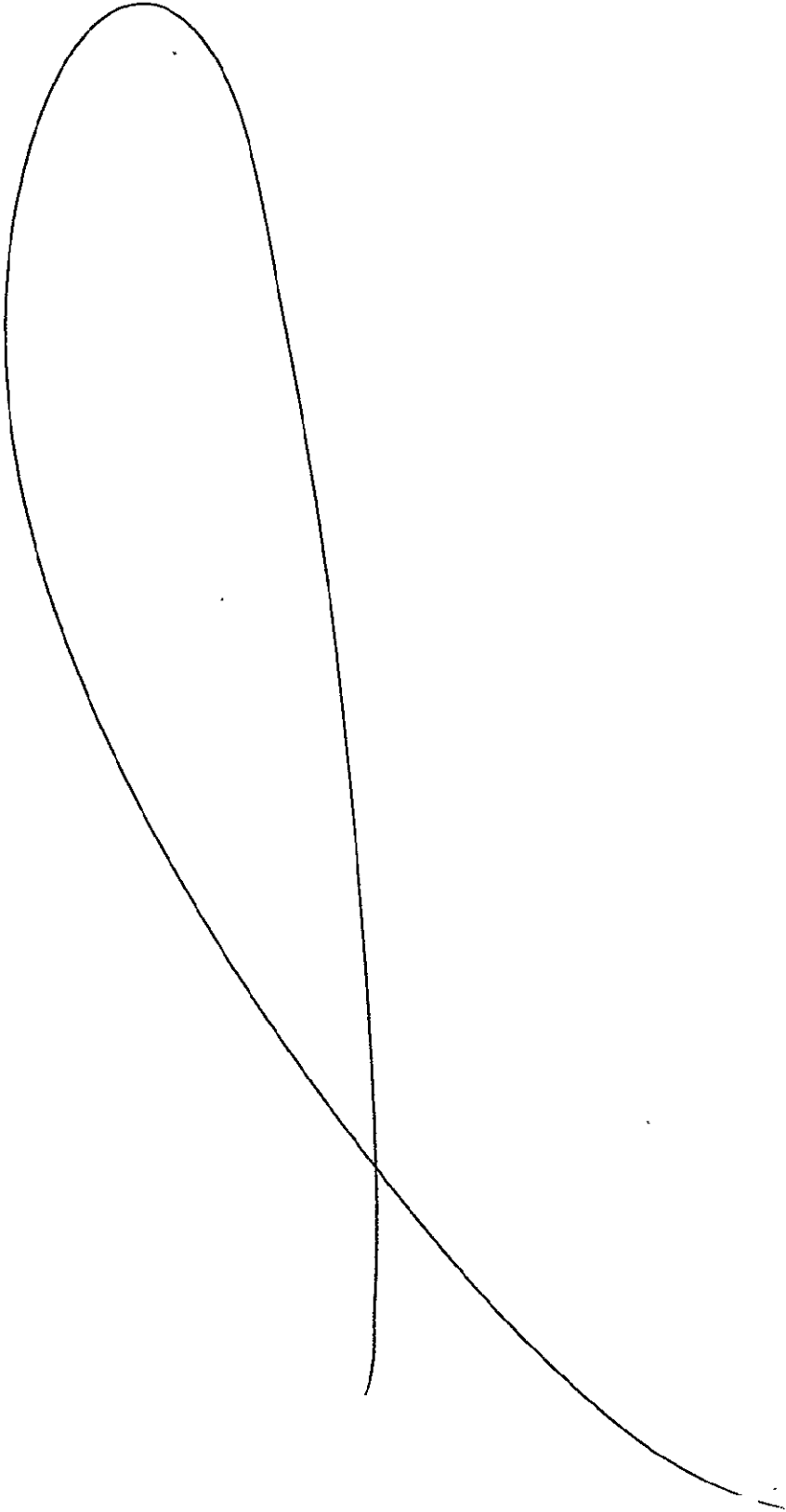
ESTIMATES OF SAVINGS FROM CONSERVATION  
ACTIONS IN SET C <sup>a</sup>

1985 $\times 10^{15}$ BTU's				
	Consumption of re- fined petroleum	Electricity consumption	Natural gas consumption	Total
1967 Base	10.7	1.2	4.4	16.3
1985 Estimated Base <sup>b</sup>	22.2	2.3	8.7	33.2
Savings <sup>c</sup> from actions in Set C	1.78	.24		2.02
Savings in coal				.75
Total Savings				2.77

a) Actions considered were 100% increased in MPG in 1985 and 25% increase in appliance operating efficiency in 1985.

b) Estimated by extrapolating 1967 base along historical growth curve.

c) Savings were computed by assuming standards affected 10% of the fleet



## CHAPTER 10. ELECTRIFICATION

The electric utility industry is a true energy delivery system in the precise meaning of the systems method. It is a major component of the energy picture today and of every scenario of the foreseeable future. As an energy system the utility industry is controlled completely by its system environment: fuel suppliers, equipment suppliers, governmental regulations, and consumption habits. In the mid-term, electricity is the major alternative to direct use of scarce fossil fuels. Electrification has been chosen for an assessment of conservation impact because it is almost the sole consumer of coal and nuclear power, and because electrical end use can be made to have higher overall efficiency than many present direct fuel uses. The important actions within electrification examined here are those with the greatest impacts (coal and nuclear), the greatest technological requirements (peak shaving and transmission) and the greatest response from the decision makers (economic health and growth of utilities in an era of increasing energy costs).

### 10.1 INTRODUCTION

Electrification will be considered as a set of actions and/or policies that leads to an increasing proportion of total energy used in the form of electricity. The increases in the amount used may come from pure growth in energy demand or from a replacement of the direct use of the traditional fossil fuels. The roughly 7% historical growth of electricity has been slowed by the Arab oil embargo and the recent slowdown of economic activity. The upward trend is expected to continue for several important reasons. One is that coal is abundant in the United States as a substitute for the more scarce oil and natural gas. Secondly, uranium has roughly four times the energy content of all our fossil fuels combined. Coal and nuclear power are expected to support the strategy of removing dependence on foreign resources. Environmental considerations have somewhat impeded the progress of electrification. Technological and economic factors may help or hinder its progress. The undercurrents of social and political activities are expected to have ambivalent effects on the electric future.

This chapter is designed to investigate the principal areas involved with electrification. The belief is held that the implications of such a broad strategy are not fully understood in terms of energy conservation. It should be noted that some of the subactions within electrification are not conservation per se, but are necessary to implement other conservation actions.

Important actions that are underway or proposed in the energy industry are discussed in Section 10.2. The coincident actions in the other sectors of the economy are dealt with in Section 10.3. Section 10.4 is the synthesis of the forces within electrification, including sector feedback flows. Section 10.5 makes recommendations based on the assumption (whether or not justified) that electrification will continue to be a major part of the U. S. energy scene.

## 10.2 ENERGY INDUSTRY ACTIONS

Of direct interest in the electrification of the U. S. economy are subactions taken by the energy industry itself. These, together with the concurrent actions of the other sectors, will have significant impact on the domestic energy future. The major actions discussed in this section involve increased use of coal and nuclear fuels and the improvement of the operations of electric utilities.

### 10.2.1 INCREASE POWER GENERATION FROM COAL

The use of coal in the U. S. now and in the future represents an ideal subject for a systems study. The final form of a coal economy is not determined now because of the many developing technologies. All phases of the coal industry are under reassessment.

The purpose here is to discuss the transition of the electric utility industry to a coal/nuclear base. The interaction of this coal market with the development of new coal intermediates and markets will be covered. The interaction of coal and nuclear energy in the utility industry will not be discussed. The two fuels vary significantly in time frame, obstacles, impacts, and technical and industrial support.

Fossil fuel power plant designs have shifted essentially 100% to coal in the last three years. There is strong support in Congress and FEA to mandate retrofits wherever possible of both power plants and process heat or steam generators. This latter action is an outgrowth of the crisis atmosphere of the energy problem. In the long view, in an electrified economy, the retrofitting of the existing plants will be a minor factor. There is evidence that this retrofitting will be delayed slightly by the too slow expansion of coal supplies.

The largest requirement in conversion to coal is not the mining, trains, or equipment but environmental and health protection. This protection requirement begins at the mine with health, safety and reclamation and continues to the disposal of the varied combustion products such as ash, dust, sulfur compounds, toxic metals, carbon dioxide, and rejected heat. There is some sentiment, prompted again by the crisis, to relax environmental standards in order to facilitate the transition in the near term. This essential requirement of cleaning up the coal system is projected to add to the cost of coal-generated electricity. This requirement is also the major obstacle to implementing coal. Along with many other elements of the energy problem, the major design decisions necessary to determine an integrated system are awaiting some near-term and mid-term development results.

The scale of the materials handling problem associated with a coal electric economy is staggering. This is compounded by the simple fact that coal must be handled several more times in its fuel cycle than oil or gas. Thus the first area of awaited developments is in the transport of coal and all the associated by-products. The transportation problem is complicated by the dispersed sources of the fuel and its concentrated consumers. Materials handling is one of the factors driving coal conversion to liquid or gaseous form. Significant problems related to delivery, handling, and storage of coal can be expected as plant sites become more scarce. A key obstacle to retrofitting existing plants is the lack of space for stockpiles and even access to railroads. Some of these problems will be reduced or eliminated if economical conversion methods can be developed. Estimates of the time for large-scale availability of coal intermediates is post-1985. [PI-74]

The removal of sulfur and, to a lesser degree, other harmful materials from coal is being attacked both before and after the combustion process. Successful clean-up of the coal or the combustion products must be accomplished immediately. Expansion of coal use from present levels will cause conflict with air standards in most parts of the country. Use of low sulfur coal predominantly will shift the mining forces and restrict expansion of the coal supply. The expense of coal clean-up impacts the utilities in two different ways. If scrubbers are used, they become part of the capital expense of the utility. If pre-combustion treatment is used the cost appears as a fuel cost. A variety of processes are under development which would yield a "clean" coal in different physical forms which implies different combustion properties and post-combustion clean-up. The combustion product "scrubbers" are beginning to show good results in tests. For some time the cost, complexity and down-time due to lack of operating experience of these scrubbers was generating great opposition by the utilities to their use. Problems of disposing of the waste products have not been solved. The scrubber units would be attached to each power plant. Coal clean-up plants on the pre-combustion side of the cycle could be located to optimize transportation requirements. Choice of a site for a coal conversion or clean-up plant would be determined by the output form (BTU of gas, liquid, or other), and the network optimization of serving several mines and possibly several power plants. Sites for coal processing will compete with sites for the power plants and other major industrial installations. There is a great opportunity for a systems study of a coal conversion plant interfacing with other heavy industry as a consumer or producer of product and energy streams besides electricity.

The technology of conversion of coal to electricity is undergoing intensive studies directed at achieving higher thermal efficiencies and at producing a waste-product stream which is easy to clean up and compatible with maximum heat utilization. Success in some areas such as magnetohydrodynamics may depend on the same processing of coal to remove contaminants as does ordinary combustion. Advanced systems such as MHD or turbine-topping cycles benefit from coal conversion also.

All of the above is intended to show the complex interrelationship of diverse technologies now under development. Coal is projected to be a growing source of electricity. Coal is projected to be a sustaining fuel for the U. S. and the world through the year 2000. This means that there is enough time to go through more than one generation of development projects. It also means that sufficient longevity of the resource exists to amortize the generations of plants not yet developed.

An orderly development of a coal-electric system would suggest growth sufficient to meet base load growth (with nuclear) until intermediate processes are developed which can simplify the handling and pollution problems. Implicit in such a suggestion is that a systems approach should be applied in redesigning the energy industry - utility interface with all of the transportation, land use, and pollution constraints applied. The creation of very large scale coal-processing industries would generate an industrial base to rival the present petroleum refining industry. The relationship of this new intermediate industry to the fuel producers, utilities, and new diversified companies has not been specified. It is a possible horizontal integration for any company in the energy industry and a possible vertical integration for the utilities.

More on the background of coal as a source of energy is found in Section D.2.1 of Appendix D.

#### 10.2.2 INCREASE THE USE OF NUCLEAR POWER

The success of the electrification strategy in energy conservation will depend to a large extent on the participation of the nuclear energy industry during the near time frame.

The justification for generating electricity from nuclear power is a matter of economics and the desire to conserve fossil fuels for other energy uses. The ratio of fuel cycle to total costs is lower for nuclear than for fossil power plants. Thus, fossil generated electricity is more sensitive to fuel price increases than nuclear. The energy content of the high grade uranium in the U. S. is about four times as great as that of oil, gas, and coal combined.

#### Nuclear Energy Industry Based on LWRs (Enriched Uranium) and HTGRs

This action contemplates the growth of the nuclear energy industry in terms of Light Water Reactors (PWRs and BWRs), fueled with enriched uranium (no plutonium recycle), and the High Temperature Gas Cooled Reactors. Forecasts of nuclear growth are shown in Figure J.2.2-1.

The time frame considered for implementing this action (nuclear power from LWRs and HTGRs) is the present through mid-term (1985). The reason for selecting this time frame is that there is sufficient information regarding nuclear power growth without the necessity of introducing large uncertainties due to extrapolations.

The necessary manpower, materials and costs requirements to achieve a 190 GWe nuclear energy industry by 1980 are based on the number of reactors in operation, under construction, and ordered but in the planning stage (Figure J.2.2-2).

The fossil fuel savings obtained by generating electricity by nuclear means is about 30 barrels of oil per day per megawatt of power operation. This means that in 1985, with 190 GWe projected, the nuclear industry will account for 5.7 million barrels of oil per day saved, or 42 billion over the 30 year plant life (for 0.65 plant load factor).

The net effect of plant scheduling and the construction manpower distribution is to shift the construction labor force to 1979 with a maximum of about 94 thousand men. This labor force is distributed over various areas in the United States.

The number of engineers required during the construction period can be calculated by assuming that they constitute 13% of the work force.

One of the major obstacles to achieving the projected nuclear industry growth is nuclear plant delays and cancellations. The factors responsible for these delays are 1) equipment delivery delays, 2) equipment component failures, 3) construction labor and equipment manufacturer employees strikes, 4) rescheduling difficulties with associated facilities, 5) changes in regulatory procedures, 6) prolonged regulatory procedures, 7) legal changes at federal and local level, 8) challenges by intervenors at federal and local level, 9) material shortages, 10) low productivity of labor, 11) weather conditions, and 12) shortages of construction labor.

According to an Atomic Industrial Forum survey, conducted in December, 1973, of 95 power plants under construction or awaiting construction permits, there were 46 delays of 47 plants under construction, 24 delays of 48 plants awaiting construction permits. The average delay time for all cases was greater than two years.

The low productivity of labor and associated declining placement rates of materials during construction are believed to stem from a combination of factors: excessive design changes, increased quality control, undesirable working conditions (congestion and activities of several crafts in one area), and insufficient engineering prior to the start of construction.

Capital cost escalation is in part responsible for some power plant cancellations. Costs have risen from \$240/KWe for plants commissioned in 1969 to about \$750 to \$800/KWe in 1975 for plants scheduled for completion in the early 1980's [Budwani-75].

### Safety Impacts

The overriding counteractions in the nuclear energy picture are plant safety and waste disposal. Appendix J reviews briefly the Rasmussen report [AEC-74-4]. This report indicated present designs have high relative safety. However, many eminent scientists and engineers and others have raised valid criticisms of the methodology and assumptions. There is no consensus on nuclear safety.

In connection with the results of Draft WASH-1400, the American Physical Society (APS) study group on light-water reactors safety [ERMP-75,S5-7] concludes and makes the following recommendations:

That the fault-free methodology can have merit in assessing relative performance of reactor systems, and in cases involving very low probabilities there is no basis for confidence in the calculated absolute values of the probabilities of the various branches in the event tree analysis.

For the same conditions assumed in the analysis, substantially larger long-term consequences can be predicted in land damage/denial and possible latent cancers in individuals who live in the areas which are contaminated below the evacuation threshold.

The Nuclear Regulatory Commission (NRC) requires that physical security plans for protection against material theft and sabotage be submitted with each application for power plant operating license, and it will not approve an application unless these plans are judged to be adequate [BUCHANAN-75].

Part 73 of the Title 10 in the Code of Federal Regulations provides for the protection of special nuclear materials at facility sites.

Increasing safeguarding requirements in the nuclear fuel cycle will make it highly improbable that special nuclear material could be diverted. However, in the unlikely event that theft takes place, proper training and special capability are needed to handle plutonium safely. A large effort at a great personal risk is involved.

Assuming that a nuclear device could be put together by a group of people, would it work? Methods to accomplish sabotage or terrorist acts, other than nuclear, exist today that can produce large public impacts with greater certainty and with lower levels of personal risks.



Safeguards in the nuclear fuel cycle will add to the cost of the electricity generated by nuclear power. The investment is well-justified considering the potential impacts on public health and safety and national security.

#### Waste Heat Impacts

At the present time, the electric power industry is responsible for three quarters of the national usage of cooling water [AEC-73-3]. As might be expected, fossil fuel plants are the major contributors to the discharge of waste heat because they are the predominant type of power plant. However, if there is a rapid growth of the nuclear power industry, the situation will change and waste heat rejection will suffer an increase. This is due to the fact that the nuclear power plants (mostly current LWR's) operate at a somewhat lower thermal efficiency (33%) than most modern fossil fuel plants of the same capacity (around 40% efficiency). In addition, 10% of the heat from fossil fuel plants is discharged directly into the air through the stack. For the above reasons, nuclear power plants discharge about one-third more waste heat to cooling water than do modern fossil plants of the same capacity [AEC-73-2].

Although advanced reactor concepts (HTGR, the breeder) will have efficiencies comparable to the most advanced fossil fuel plants, their eventual widespread use will not eliminate waste heat problems. The rate of increase of electric generating plants, and thus the waste heat produced, is so rapid that the relative efficiency of the plants is not the single most important factor in alleviating the problem.

Consult Appendix J.2.2 for data on waste heat and climatic effects.

#### Nuclear Waste Disposal Impacts

Current NRC regulations require that commercial fuel reprocessors convert all high-level radioactive wastes to a stable solid material within 5 years after separation in the fuel reprocessing step, encapsulate them in stainless steel canisters, and ship them to a federal repository within 10 years of its production for long-term management by NRC-ERDA.

ERDA has a waste management program (funding for 1976 is \$36 million) which includes the site selection and conceptual design of a pilot plant facility for disposal of radioactive waste in bedded salt mines. Investigation of disposal in other geologic formations is also being considered [AEC-74-1]. The overall objective of this program is to have facilities for the permanent disposal of nuclear waste demonstrated and in full-scale operation around the mid-1990's.

In the meantime, NRC is moving ahead with a project to construct a federal repository at an undesignated site for retrievable storage of high-level waste from commercial fuel reprocessing plants. This is referred to as the Retrievable Surface Storage Facility (RSSF). The RSSF will safely store the nuclear wastes above ground and in a manner that will enable the waste to be retrieved for a more permanent disposal. The design criteria of this facility is that the nuclear waste can be safely isolated for centuries, if necessary.

The optimal flexibility of near-surface storage is acquired at the expense of extensive surveillance, and could leave the wastes vulnerable to acts of man such as war and sabotage.

Impacts due to nuclear waste disposal, other than high level, are presented in great detail in Appendix C of [MEGASTAR-74].

### Economic Impacts

There seems to be no serious economic impacts in achieving the nuclear growth as projected by actual commercial power plants ordered through 1985.

A potential obstacle to the growth of nuclear power could be the capital cost escalation. Presently, capital cost is about three times more than it was around 1969.

Additional costs are those related to the security program needed in the fuel cycle to prevent the loss or diversion of special nuclear materials and the decommissioning of nuclear power plants after their useful life. \_\_\_\_\_

### 10.2.3 IMPROVE OPERATIONS OF PUBLIC UTILITIES

Since the action as stated is very complex, a basic distinction will be made at the outset. Although the two are very strongly interrelated, the technology and economics of utility operations are dealt with separately. Logically, the former is included in the latter.

The electrical utilities are facing many challenges resulting from rising costs of generator fuel and deteriorating load factor (average load/peak load.) The load factor is particularly important because capital requirements are driven by peak loads, whereas revenues are derived from total load. This situation forces utilities to retain older, inefficient generators to meet peak loads, or to acquire relatively expensive new peak generators (typically simple cycle turbines inefficiently burning scarce fossil fuels) for peaking purposes.

Load-shaping technology is concerned with the maximization of the use of the more efficient base-load generators by minimizing load peaks through the applications of such technology as storage devices, power pools, and ripple load controls. Generally, there are two basic methods for re-shaping of a utility's load curve through cooperative action with affected customers. Indirect methods involve creating customer inducement to shift demand away from system peak, leaving to the individual customer control over the extent to which his particular load at system peak is reduced. Direct methods of load management vest a smaller degree of load choice in the customer, while giving the utility direct control over certain portions of its load. While the customer may retain some power to decide his load, once he does place a load on definable service, he relinquishes immediate control over the supply of electricity to that load.

#### 10.2.3.1 THE TECHNOLOGY

Two areas of greatest need for advanced technology are storage and transmission.

##### Energy Storage Systems

The basic dilemma for most electric utilities are marked daily, weekly, and seasonal variations in demand of electric power. Thus, a utility must generate power economically over a large swing of the electric load. At the same time, its generating capacity must be large enough to satisfy the maximum demand plus the reliability requirement of a sizeable system reserve.

Base load plants are used to serve the part of the system load that continues for 24 hours a day throughout most of the year. They are designed to operate with the highest level of efficiency and reliability on the least expensive fuels. Base load generation is now served primarily by modern fossil steam plants. Nuclear steam plants will serve an increasing fraction of the base load.

The intermediate load range, which comprises the broad daily demand peak of a typical utility, is served by several different types of generating equipment. This equipment typically comprises a utility's older, less efficient fossil steam plants and gas turbines.

The peak load demand, which may range from a few hours to perhaps ten hours a day, is usually satisfied by a system's oldest and least efficient fossil steam plants and increasingly by gas turbines.

Energy storage systems must, however, meet the utility-type standards for operating life, reliability, safety and environmental compatibility of generating equipment. Moreover, the total annual cost of electric energy obtained from energy storage systems must be equal or less than the cost of energy from non-storage equipment used for peaking.

If electrical energy could be generated during times of low demand (at night for example) and stored for use during times of high demand, there could be the following beneficial results:

- Storage units could effectively increase the capacity of the power system with energy generated in off-peak hours.

- Storage units could enhance the overall economics of the power plant by altering the larger and more efficient steam base load units to account for more of the total power generated.

- Energy storage could also reduce the requirement for increasingly expensive fossil fuels used for intermediate power generators by coupling storage with nuclear generation.

- Energy storage could form part of the utility system's spinning reserve, if the stored energy can be delivered at sufficiently high rates.

At present, the three most attractive options appear to be batteries, underground pumped hydro, and compressed air storage. Batteries have the edge because of transmission and distribution credit potential derived from dispersing them throughout the system. Thus, concentration of research and development efforts on these three types of storage is recommended.

#### Advanced Transmission Systems

The electrical industry is faced with a need for dramatically larger generators to optimize the utilization of larger new power sources such as the gigawatt-capacity fast breeder reactor. For the first time in the evolution of power generators, superconductivity is available to the electric machine designer. According to [Flynn-73], the technological leadership in superconductivity machinery in the U. S. could help reduce generator imports by up to 50%. The technology can be exported profitably by U. S. companies through licenses and joint ventures. On the other hand, the availability of less costly and more efficient means for underground transmission of large blocks of power may be a significant factor in determining the ability of electric power industry to meet future demand. The present technology of underground power transmission has much to be desired when one looks ahead to the anticipated requirements. Underground superconducting power transmission lines appear to be an attractive alternative to present technology. [Meyerhoff-73]

### 10.2.3.2 THE ECONOMICS

Electric utilities, whether privately or publicly owned, are regulated monopolies in the power industry. Much of the rate regulation comes from state and public utilities commissions. The Federal Power Commission establishes accounting practices while the Securities and Exchange Commission regulated equity and bond issues. Several other agencies are involved with siting plants, rights-of-way, environmental standards and many other areas. As noted in Chapter 1, each of these regulations enters into the profit calculation of the utility. The revenues come from the sale of electricity. The costs involved are largely plant construction and heavy machinery, but include operation and maintenance costs. The latter do not vary significantly with output. Some of the money for fixed investment comes from internal savings and some from the money markets. Taxes are paid on the difference between revenue and income. Table J.2.3.2-4 gives an example of an income statement of the Alabama Power Company for 1973 [APCSR-74]. This focuses the preceding discussion, and provides an anchor for the discussion of subactions. The subactions discussed in this chapter are essentially a combination of those suggested in Project Independence [PI-74], the National Power Survey [FPC-F0-74] and various other sources. They are by no means original to this study, but they remain important areas for policy changes.

#### The Rate Structure

The most obvious action that can be taken by any public service commission is to allow an increase in electricity prices. This has an immediate effect on the revenue of the utility. Many utilities have been allowed rate increases over the past several months. In fact, automatic fuel adjustment has become part of many rate calculations.

The pricing of outputs of electric utilities has been a problem facing society for several decades. In this industry with extremely large fixed costs relative to operating costs, the economies of scale cause the per kWh (average) cost to decrease as output increases. The cost (marginal) of producing each additional kWh decreases faster than the average. It would be most desirable for the price of a kWh to be set according to the amount it costs the utility to produce that kW. This assumes that the reward to management activity (normal profit) is included as a cost to the firm.

One problem with pricing electricity according to marginal costs is that since these are always below unit costs, total costs will exceed revenues and profits will be negative. Another problem is that if the rule of setting price equal to marginal costs is not followed, the attempt will always be made by the firm to increase output until size problems become unmanageable.

There is ample justification, then, for concern about utility rates. Some suggested pricing plans are to price at marginal cost and make up the difference from state and local tax revenues, price at average cost to break even, or charge a fixed fee to use the service and price the output at or near marginal cost. The latter is currently used in many of the utilities today.

A second important area relating to rate structure is the peak versus non-peak usage of electricity.

Figures 10.2.3.2-1, 10.2.3.2-2, and 10.2.3.2-3 show the representative daily, weekly and yearly peak loads for a metropolitan utility. As mentioned above, the utility must maintain the capital equipment to deal with the peak demand. Older and more inefficient equipment is used to achieve the peak, causing costs to rise. Depending on the size of the peak to trough gap, other equipment must also lie idle. Idleness is a property of plants under construction. The construction of the hardware usually takes about four years, while the legal and environmental processes last for an indefinite period, especially for nuclear plants.

The daily load profile shows that the seasonal factor also enters the picture. The weekly picture shows that the difference between the day and night periods is roughly 2.5 Gigawatts. With an average load factor of 61% [Rybeck-75], the utilities need to increase the load for which there is a constant demand over time. This comes in large part from the big users, and is shown as base load in Figure 10.2.3.2-3. Demand above base load for the two utilities occupies a relatively small percent of time. This is detrimental due to the capital requirements mentioned above. Base load users are given preferential rates because of their large reliable purchases. This is the third area of importance in the rate structure.

In many places of the world and in the domestic telephone utilities, the customers are charged different prices for peak and non-peak uses. This increases the revenue of the utility from per-unit peak sales, but also is intended to discourage peak use and encourage use during off-peak hours. In Figure 10.2.3.2-2, this would be seen as flattening the tops and raising the valleys.

Electric utilities have been asking for action by government related to their rate structures. They have generally been granted rate increases, even to the extent of having automatic "fuel adjustments" to customer utility bills. Higher prices are expected to decrease demand. The degree to which this occurs depends on the price elasticity (cf. Section 1.2.1 Chapter 1) of electricity. The latter has been estimated to be around 1 [Houthakker-74]. This means, for example, that if rates go up by 20%, electricity purchased will go down by that amount. The important thing is not that demand go down per se, but that it go down selectively.

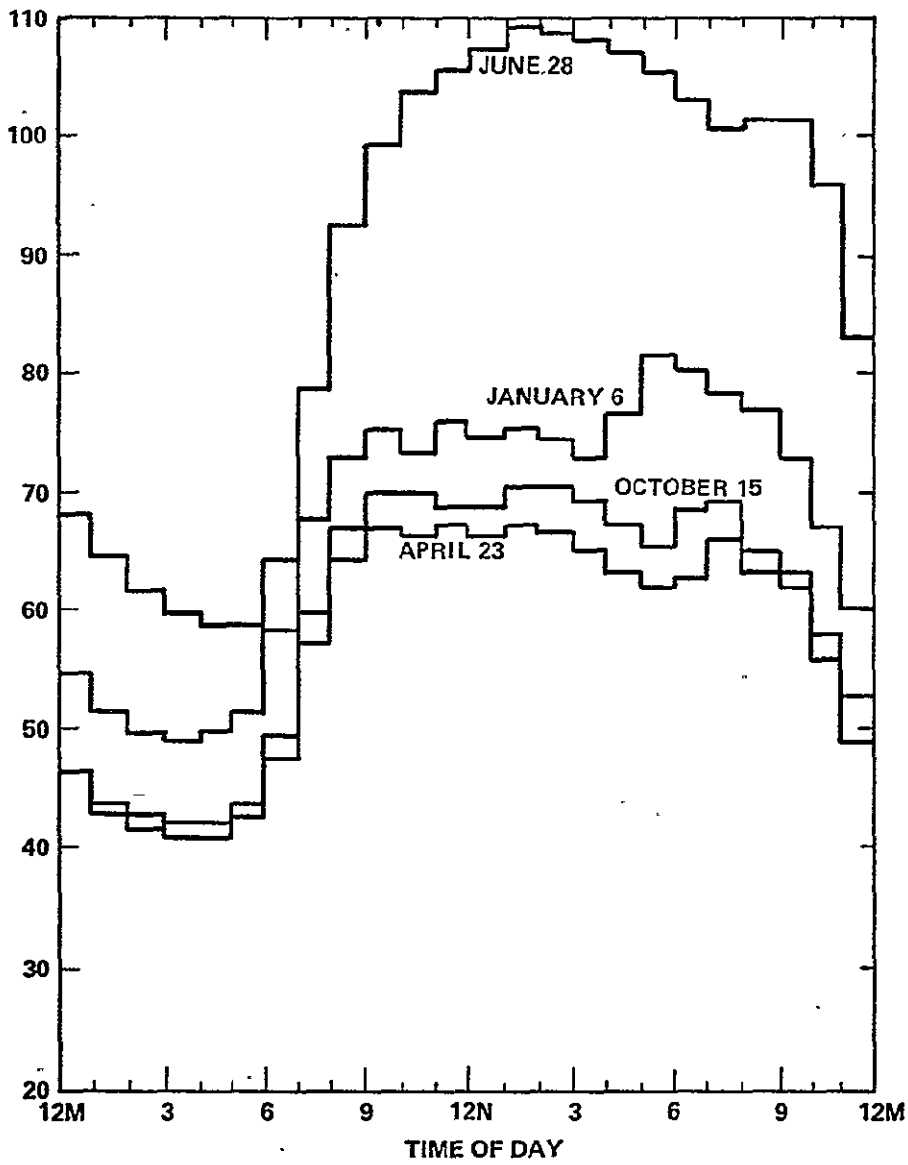


FIGURE 10.2.3.2-1 DAILY LOAD PROFILE

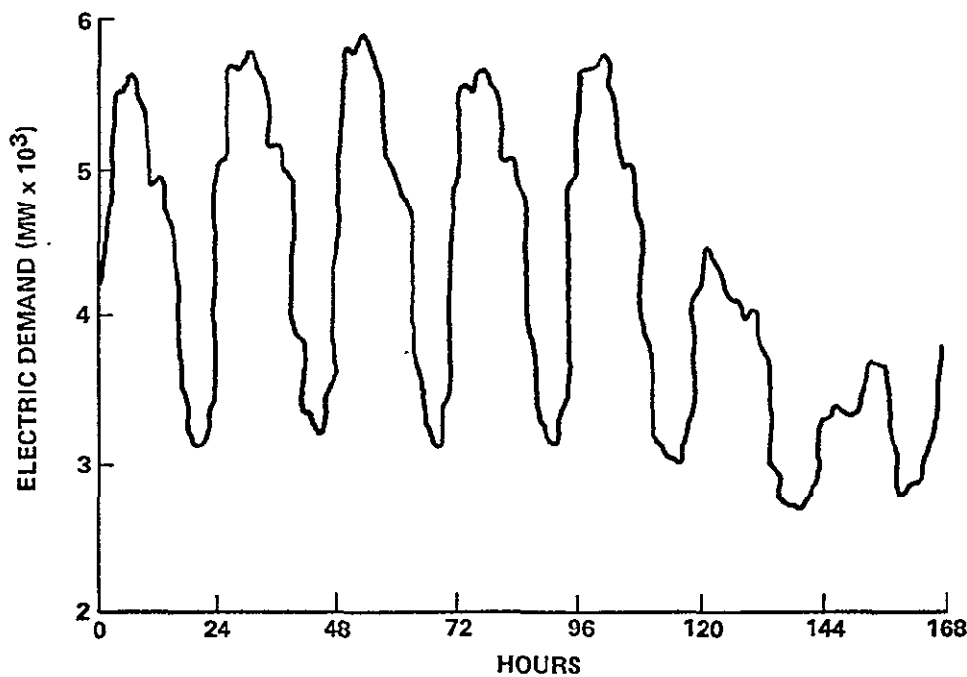


FIGURE 10.2.3.2-2 TYPICAL WEEKLY LOAD VARIATION

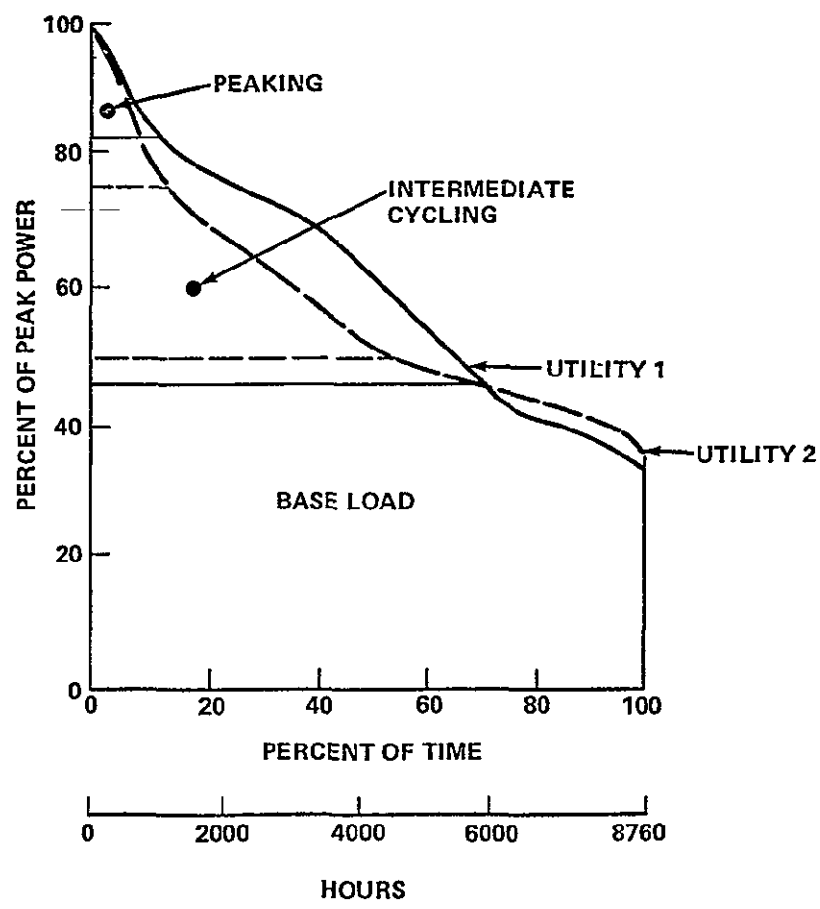


FIGURE 10.2.3.2-3 YEARLY LOAD DURATION



Peak electricity pricing has not been instituted in the U. S. at the time of this writing. Its prospects are uncertain. Project Independence [PI-74] estimated that the savings resulting from a 10% reduction in peak load via pricing and/or the metering, transmission and storage techniques mentioned above, would be approximately 2.6 quads by 1985.

There is currently a popular movement to remove price discrimination by electric utilities. At the present time, small users are charged higher prices than large users. This is said to encourage increased use of electricity, contrary to conservation by reduced use. Utilities appear to obtain more revenue from this type of discrimination since one class of users cannot buy cheaply and sell to the other. The buyers' demands are, of course, different. Utilities basically want to reward large users for providing base load demand by charging lower rates. An inversion rate structure will most likely make the utilities position worse, given that they must reward their investors. The people's position may also be made worse by a move which ostensibly seems to help them.

### Regulatory Reform

Along with rate modification to help in peak-shaving, the Technical Advisory Committee on Finance of the National Power Survey [FPC-F0-74] recommends a strong movement to implement precise cost control by utility managers, an education program to make the public aware of utility problems, and regulatory reform. The latter would entail

- Streamlining accounting practices (FPC) to maximize internal cash generation

- Stimulate and reward overall savings and investment (Federal Reserve Board)

- Re-evaluate environmental goals

- Continue utility joint-ownership and financing

The first action includes the retention of several accounting practices (e.g., investment tax credits and accelerated depreciation) that have benefitted utilities in the past. New suggestions are to increase the investment tax credit, extend the use of favorable depreciation rules, include plants under construction as a current expense in rate base determination, normalization ("...spreading tax benefits related to plant investment over the useful life of the plant..." [FPC-F0-74]), tax deferrals, and price-level indexing policies.

The second action basically would be implemented through manipulation of interest rate. It would not be expected to have much success during the current inflation.

The strong impetus to redeem the U. S. ecological system has led to many restrictions on power plant siting and operation. The third action suggests that a more careful calculation of the costs and benefits of the environmental standards be undertaken. This will be particularly important if coal and nuclear power are used more extensively. Current emission-control technology is very expensive and costs increase rapidly as the percent removal requirement approaches 100. If standards are lowered, utility profitability will be enhanced.

The last action relates to the benefits of pooling financial resources, and may have an important role in establishing increased interregional transmission of power.

### Combined Effects

As noted above, rate structure and regulatory changes affect profits in analogous ways. Under the present private enterprise system (80% of utilities are investor owned), profits must be large enough to reward investors and contribute to future construction plans. Table D.2.2-5 shows that during the most recent period of growth of electricity, the percentage of construction funding generated internally has decreased significantly. This causes utilities to go to the financial markets and pay higher prices for the money needed. This, then, has further depressing effects on profits.

## 10.3 ACTIONS IN OTHER SECTORS

A strategy as broad as electrification involves significant interaction among the sectors. In this section, the most important actions in industry, transportation, and residential/commercial sectors will be considered.

### 10.3.1 INDUSTRY

The justification of electrification within industry is primarily a matter of shifting from direct energy fuel use. There are process areas which can make changes that decrease energy use, such as furnace technology in the steel refining industry.

The requirements for a shift to electric furnaces in the steel industry are economic growth, available capital, integrated process, large scale electric generation and reliable supplies of scrap steel. Economic

growth and available capital are general concerns with any major shift in technology. There is always cautious optimism within a given industrial sector. The integrated process is necessary to make energy savings and requires major process changes prior to the point of using the electric furnace. The requirement of large scale electric generation is necessary to insure a reliable supply of electricity over the lifetime of the process equipment. A reliable supply of scrap steel is the critical issue to make the shift an energy saver. Scrap steel is introduced to eliminate a sizable portion of prior energy consumption.

The time frame for the shifting action is effectively 10 years. A major shift from the open hearth to basic oxygen furnaces was accomplished over 10 years with the effect of reduced energy consumption for the steel industry.

The potential impacts of the shift to electric furnaces are integration and increased flexibility of steel refining. The integration would give steel manufacturing increased flexibility and provides a technical means for the production of alloy steels.

Among the major obstacles is the reliability of iron scrap recycling. It is difficult to provide an effective removal of discarded products from the waste stream without large social, political and economic impacts. The most general obstacle is economics since there is a trend toward business-as-usual rather than making major shifts in technology.

The concept of cogeneration as a possible energy conservation action has been discussed in Section E.5.2. Although this action offers considerable savings due to the increased efficiency of the process which utilizes the steam produced during electrical generation, many obstacles to its implementation exist. Some of the most obvious barriers to implementation have been discussed in Sections E.5.2 and E.5.6. A great deal of cooperation between utilities and industry would be required in order for the concept to be viable. However, if the additional capacity needed by utilities could be provided by retrofitting industries capable of cogeneration, perhaps a reduction in capital expenditure as well as a reduction in energy consumption could be obtained.

The industrial sector is the largest user of electrical energy, accounting for 70 percent of consumption in 1972. The wide range of power uses, coupled with the relatively large blocks of power used by industrial customers, suggests many possible load management techniques. Three aspects of load leveling exist:

Interruptible power

Permanent shifting of loads to off-peak so that times of peak power use do not coincide with utility's peak demand

Peak self-generation and storage of energy during off-peak periods for use in peak periods.

It is obvious that the extent to which these techniques (or some combination,) are applicable to a specific industry must be determined by some in-depth analysis.

In general, industry is reluctant to accept anything but a defined frequency and guaranteed very limited duration of interruption. It is known that smelting is the most energy intensive process -- the production of aluminum. Although current practice is to operate continuously, there is a good possibility for shutting down for up to a maximum of four hours daily during on-peak hours. The price would include the installation of additional cells and the hiring of operating personnel to maintain daily production levels. It may not be necessary or desirable from a load management point of view to consider interruptions of power each day throughout the year. For interruption only during utility seasonal peak demands, a better measure of the cost to the industrial customers might be the total value of output.

There is also little success in getting industry to shift its pattern of electricity consumption (to three shifts if less are used; to weekends; to daily off-peak periods.) This is ascribed to the fact that the savings in rates would not justify the cost of additional investment and/or labor costs. For many industries, electric energy constitutes only a small fraction of total energy use and total expenses. Rate differentials would have to be very significant before industry changes its pattern of consumption. However, there appears to be a potential for a significant shift to off-peak electric energy for iron melting in foundries, electric steel making, glass melting, and crushing and grinding in industries such as cement.

Energy storage through pressurized air represents a viable load management technique for industry. Load management can be accommodated with the addition of a receiver which would provide sufficient storage during peak demand periods.

One should not forget the societal effects of restructuring the working hours in case of added labor for new shifts. A common deterrent to second and third shift operations in industry is the inability to attract qualified workers. In addition, schedules may have to be flexible as utility system demand patterns change due to either increased electricity use or the adoption of load deferral techniques by other users.

### 10.3.2 TRANSPORTATION

Many important areas of impact are found in the transportation sector. These include fixed-rail systems, battery-operated systems and alternate fuels made from electricity. Since these alterations of end use rely on complete systems redesign and considerable as yet undeveloped technology, they will be discussed in Appendix J.

### 10.3.3 ELECTRIFICATION OF RESIDENTIAL AND COMMERCIAL HEATING, VENTILATING, AND AIR CONDITIONING SYSTEMS.

The principle change here is the adoption of heat pumps and limited thermal storage.

## 10.4 CONSERVATION FEEDBACK AND IMPACTS

The question has been pending whether or not electrification implies conservation. This can be answered with reference to the three modes of conservation.

If electrification is built largely on coal and nuclear fuels, then it will achieve conservation through substitution for domestically scarce fuels.

Given the 60-70% energy conversion losses of power plants, the use of efficient electric devices such as the electric furnace, electric car and electric heat pump can partially make up for them.

If coal and uranium are in high demand due to the scarcity of other fuels and rigidities in production and conversion, then the price of electricity most likely will increase relatively more than other prices. This will cause a reduction in the consumption of electricity.

The major area of conservation appears to be that of substitution for oil (especially imported oil) and gas. Power plant conversion efficiencies apparently cannot be easily improved in both the technological and economic senses. The average coal and nuclear plants are respectively about 40% and 33% efficient. The rest of the energy is essentially lost in the present system. The degree to which these losses are made up by electric devices depends, of course, on how technically efficient they can become and how widespread their use. Conservation by curtailed end-use may be motivated by higher electricity prices, but will depend on a myriad of other forces. Although the latter are discussed in several other places throughout this report, no assumptions about them will be made here.

The major impacts of electrification in the energy industry itself are well-known. Among them are:

Topographical disruption will result from strip mining and deep mining

Labor will shift to coal and uranium regions and to electric industry-related occupations.

The transportation of fuels will be accomplished to a greater extent by improved railroad systems.

Electrification will mean a proliferation of power plants. Some effects associated with these are:

Pressure on money markets if the capital-intensive public utilities are not able to obtain internal financing.

Siting problems caused by waste heat and other discharges into the surrounding air and water.

Increased rights-of-way needed by transmission lines causing esthetic problems.

Power plant proliferation implies a movement to central station conversion from direct fuel use. This will concentrate environment discharges, allegedly away from population areas. The climatological effects of concentrated emissions are becoming significant as the size and number of these plants increase. This is of special importance since there are now advocates of clustering several plants in certain geographical areas.

The major capital problem of the electric utilities is apparently the peak load problem. Utilities must maintain the capacity to supply its consumers needs during heavy use periods. As noted above, they generally use older and less efficient equipment to cover the peak. Also, other equipment is left idle if the trough is deep. This is very expensive for the utilities. They are trying to encourage off-peak use as well as increase their base load. Some of the actions mentioned above are important for peak leveling. These are the use of storage, peak metering and peak pricing.

There are particular problems associated with the nuclear industry. A potential obstacle to the growth of nuclear power could be the capital cost escalation. This has been, in part, responsible for some power plant cancellations. Costs have risen from \$240/kWe for plants commissioned in 1969 to about \$750 to \$800/kWe in 1975 for plants scheduled for completion in the early 1980's.

Additional costs, which at the present are not factored into the price of electricity, are those related to the security program to prevent diversion of special nuclear materials and the decommissioning of nuclear power plants.

Nuclear waste management is an area of great concern. At the present time, there does not exist a permanent type waste disposal method for high-level radioactive wastes. Long storage of high-level waste is under research and development and an acceptable disposal method is not to be available before 1995.

A reactor safety study, Draft WASH-1400 [AEC-74-4], made a realistic estimate of the risks from potential reactor accidents and compared them with non-nuclear risks to which our present society is exposed. The results clearly indicate that non-nuclear events, such as fires and air crashes, are about 10,000 times more likely to produce large accidents than nuclear plants. Also, nuclear plants are about 100 to 1000 times less likely to cause comparable large dollar value accidents than other sources. The study also concludes that the number of injuries from a reactor accident are insignificant compared to the 8 million injuries caused annually by other accidents.

The potential of plutonium as weapons-grade material and as a high radio-toxic biological poison presents a dangerous situation to national security and public safety. Increasing safeguarding requirements in the nuclear fuel cycle will make it highly improbable that special nuclear material could be diverted. However, in the unlikely event that theft takes place, proper training and special capability are needed to handle plutonium. A large effort at a great personal risk is involved.

Nuclear power plants discharge about one-third more waste heat to the cooling water than do modern fossil plants of the same capacity. Heat releases from large power plants are comparable with the heat discharges from other events that have caused perturbations and climate changes of appreciable magnitude.

The factors involved in an analysis of the effects of thermal loading of a particular aquatic system are very complex, and no single index (such as a change in fish catch) can provide an adequate testimony to the effects of a particular installation.

Based on DOT accident statistics, we can calculate how many accidents involving nuclear shipments might be expected each year. Assuming 100,000 truck-miles per year of transportation for each nuclear power plant and with 190 such plants by 1985, one can expect about 10 accidents per year. Those accidents will produce 24 injuries and about 3 deaths per year. In the case of rail shipments, assuming 15,000 railcar miles per year per reactor, there might be about 5 accidents with 11 injuries and 11 deaths per year. These deaths and injuries would not be related to the nuclear nature of the shipment.

The vast majority of accidents involving nuclear shipments will result in no release of nuclear materials, or injury or death due to radiation. In the Price Anderson Act there are no provisions for damages produced by misuse of nuclear materials at locations other than nuclear plants and planned transportation routes.

Except for the peak problem, these impacts are common knowledge to most Americans. Each action, however, entails secondary and higher-order impacts. Figure 1.2.3-1 in Chapter 1 can be used as a guide to trace these through the system. The time and resources of this study presented a constraint on how well these ripple effects could be analyzed. Some of the more important of these are mentioned:

Energy Industry -- Industry Interface. The electric furnace can be utilized more extensively. Cogeneration of process heat and electricity may occur. Industry must produce the electrical equipment for other sectors.

Energy Industry -- Transportation Interface. Electric vehicles and rail systems may present night-recharging load for utilities. Alternate fuels may be generated at power plants.

Energy Industry -- Residential/Commercial Interface. Electric heat pumps, ranges and water heaters will increase electric load demand, some of which may occur at peak periods. People must adapt to mass transit and other sources of life-style changes.

Conservation in general will most likely have ambivalent effects on the energy industry. Through increased efficiency, substitutions for scarce resources and curtailed use in the energy system, the total energy used will probably go down. Substitution of fuels, however, does not necessarily imply this.

The effect of conservation on public utilities has been estimated in [Rybeck-75] for 1980. As shown in Table 10.4-1, conservation appears detrimental in almost every area. Selected reduced use, i.e., in peak periods, will be the greatest boon to the electric industry.

More studies must be done on the net energetics of electrification. This was attempted in Section C.3 of Appendix C. In terms of the criterion of decreased dependence on OPEC, electrification does well. It remains to be determined how well it meets the criteria represented by the will of the majority in the U. S. today.

The conclusion of the group is that electrification can be a conservation strategy. It has both positive and negative impacts, and the relative weights must be determined. It most likely will be a large part of the U. S. energy future, even by 1985.

## 10.5 RECOMMENDATION

The following list summarizes the major recommendations that relate to the study of electrification. Probably the most important ones belong to the improvement of the load-factor (which is the backbone of the utilities) and to the rate structure (see Figure 10.4-1).



TABLE 10.4-1. COMPOSITE PROJECTED TO 1980  
(7 PERCENT INFLATION IN LABOR AND MATERIALS AND  
9 PERCENT COSTS OF Aa BONDS) [Rybeck-75]

Management Philosophy	1/1/75	1/1/80	
	Historical Growth	Conservation Strategy	Managed Growth
kWh growth rate	7%	2%	10%
Peak load growth	8%	4%	8%
Load factor	61%	55%	67%
Earnings/share	\$ 2.38	\$ 1.68	\$ 2.83
Common stock prices	\$19.00	\$15.31	\$26.92
Bond rating	Aa	Baa	Aaa
¢/kWh	2.43¢	2.85¢	2.81¢
Rate Increase		3.7%	3.7%
Capital Requirements			
Total (millions \$)		64,500	134,400
Internal (millions \$)		31,400	38,700
External (millions \$)		33,100	95,700
Utility Long-Term Financing as a Percent of Total Capital Avail.	11%	4.4%	12.8%

ORIGINAL PAGE IS  
OF POOR QUALITY

Create a more stable base for future coal, nuclear and hydro generated electrification of the economy, as an alternative to the direct combustion of scarce fossil fuels.

Increase efficiency such that by 1985 the annual growth rates of electricity usage (kWh) and peak demand (KW) should be cut from their historical seven percent to no more than five percent and four percent respectively.

By 1985 the average load factor should be improved from the present 62 percent to about 69 percent.

Expand transmission system interconnections (power pools) to improve efficiency, reduce the requirement for inefficient peak-load generators and to maximize the use of installed capacity.

Provide conservation merit awards and widespread publicity for those utilities which have taken positive actions to reduce inefficiencies in the generation, distribution, and end use of electricity.

Perform an analysis of the potential for improving efficiencies of installed electric power generators, as well as improving state-of-the-art conversion efficiencies of new plants.

Encourage mixed heating systems where the relative proportions of storage and direct heating are set to minimize capital plus operating costs, and to avoid the uneconomical design of a heat pump to supply peak heating demand on the coldest days of the year.

Adopt an off-peak tariff for storage heating on a separate circuit with separate metering.

Develop methods and equipment which would permit work on energized overhead and underground conductors to be performed rapidly with maximum safety to workmen.

Initiate programs to improve communications and interchange of personnel between the academic community and the electrical utility industry.

Perform extensive studies to determine relationship between energy price and the amount of energy used (elasticity studies.) Studies should include: elasticity by class of service, and by states or appropriate regions of the nation.

Develop detailed information on the cost of service by customer class and by time of day (for example: on or off peak.)

Study the roles of the tax and regulatory systems in perpetuating or changing demand patterns by means of depreciation policies, depletion allowances, tax subsidies, zoning regulations, and building codes.

Establish comprehensive research program directed toward the development of understanding of the determinants of energy demand. This will shed the light on the factors which determine economic elasticities of demand, and also illuminate the relationship between energy use and standard of living.

Support demonstration projects for cryoresistive 80° K systems.

Establish applied research on properties of cryogenic materials (dielectrics; superconductors to operate above 12° K).

Required engineering development of: improved cryogenic insulation; reliable installation techniques; efficient, more reliable and less expensive cryogenic refrigeration.

Establish demonstration projects of AC & DC superconducting systems.

Explore development of cryogenic terminal equipment.

Use of hybrid systems such as managing steel flywheels for regenerative energy storage. This would save losses during braking downhill and/or to a stop. More important, it would help provide the added power needed for acceleration and going up grade. This means a smaller size requirement and also lower peak demand -- a vital factor concerning rates from the electric utility.

To capitalize on electrification, the railroads could own and operate electric trucks and material-handling equipment at each terminal. In this fashion, they could move the goods to the customers' doors and thus capture freight business now handled by trucking firms.

In the passenger realm, promote use of the auto train. In this manner, the passenger's automobile (perhaps electric) would go along with him. He would not refrain from riding the train simply because he needed his car at his destination.

As an alternate and/or supplement to the above, the railroads could doubtless attract more passengers if they could provide a low-priced auto rental (probably electric) at each terminal. Again, the passenger would have the advantage of flexible automotive transportation at his destination without the expense and fatigue of the long driving trip on the highway. Furthermore, this would overcome the disadvantage of the short cruising radius of the electric automobile. It may prove less risky for the railroad to rent battery powered vehicles than those fueled by gasoline.

## CHAPTER II. DIVERSIFICATION OF ENERGY SOURCES

//1/

This chapter introduces the concept of energy source diversification as a substitutional conservation action. The current status and philosophy behind a diversification program is presented in the context of a national energy policy. Advantages, disadvantages (constraints), and methods of implementation for diversification are discussed. The energy source systems for diversification are listed and an example impact assessment is outlined which deals with the water requirements of the specific energy systems. Further details of the diversification study are given in Appendix K.

## 11.1 DEFINITION AND BACKGROUND

## 11.1.1 DEFINITION

Diversification, on the other hand, is not an overall energy conservation policy. It does not explicitly pursue methods for curtailment of sector. Diversification, therefore, implies conservation through substitution for scarce energy resources. Its philosophical underpinnings reflect an awareness of social, political, environmental, and economic difficulties inherent in a program of energy system concentration and seeks systematically to avoid them.

Diversification, on the other hand, is not an overall energy conservation policy. It does not explicitly pursue methods for curtailment of energy use; it does, however, advocate that energy resources be used more wisely and to that extent is compatible with any program which emphasizes curtailment and greater efficiency.

## 11.1.2 BACKGROUND

Since the beginnings of industrialization in western culture, societies have tended to become dependent on one or two major energy sources. England, prior to the industrial revolution, relied primarily on wood. As population and industry grew, wood became a scarce commodity. Production and use of coal increased until it became the dominant source of fuel. A similar pattern of energy use has been plotted for the U. S. and is displayed in Figure 11.1.2-1. Study of this figure indicates that it has taken around 60 years for coal and petroleum sources to grow from infancy to maximum use, at which point they begin to be replaced by other sources. A policy focusing on diversification of energy sources suggests a change in this pattern of growth and decline of single energy sources.

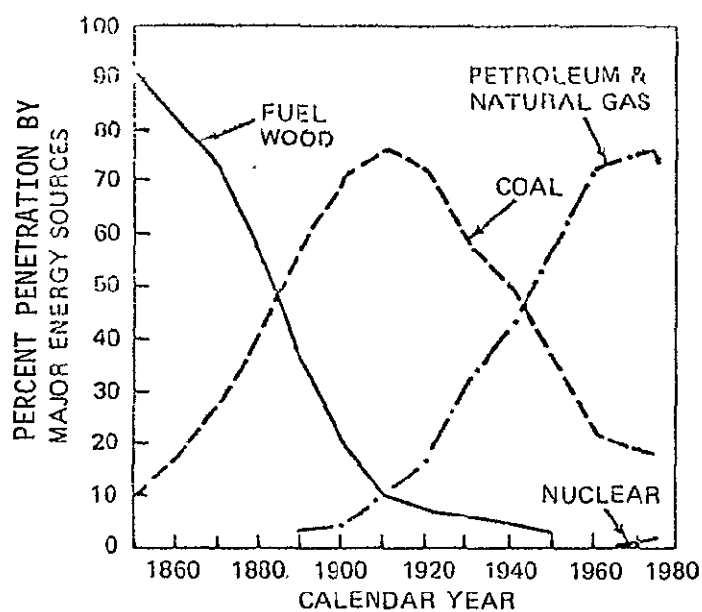


FIGURE 11.1.2-1. U. S. ENERGY CONSUMPTION PATTERNS [ERDA-48-75]

SOURCE: HISTORICAL STATISTICS OF THE UNITED STATES BUREAU OF THE CENSUS: U. S. BUREAU OF MINES, 1974

Diversification implies a desire for the future development of a variety of sources, or at least a reduction in the uncertainties concerning a variety of sources so that options for choice will be available when decisions need to be made. ERDA in its first National Plan [ERDA-48-75] echos this purview by suggesting that one of its goals will be to shorten the energy system maturation cycle from the historical 60 years to 30 or less.

In reflecting upon the contemporary situation in energy and observing historical trends, mind sets, attitudes, and public policy debate, it is apparent that many contemporary energy problems are related to the fact that the U. S. let itself become a "mono-energy culture" largely dependent on petroleum sources. In some sectors such as transportation, this dependency upon petroleum is almost total. Because of the problems associated with such exclusive reliance on one major energy source, many individuals and institutions are beginning to ask if there might not be a better way to move into our national energy future rather than to again get caught up in a nearly single supply system.

## 11.2 THE SYSTEMS APPROACH TO DIVERSIFICATION

As outlined in Chapter 3, the systems approach is simply a logical way to investigate a problem. The systems study of energy diversification was initiated for the reasons alluded to in Section 11.1 above. Basically, energy diversification appears to be a path the U. S. might follow in the coming years. With this in mind, the systems diagram for the study of energy diversification was prepared as shown in Figure 11.2-1.

### Objective

The stated objective of the diversification investigation was:

Study energy diversification and its impacts.

### Requirements

The requirements deemed necessary to meet the objective are listed below (also see Figure 11.2-1).

Determine the current status of diversification

Determine the advantages and disadvantages of diversification

Determine the constraints and criteria

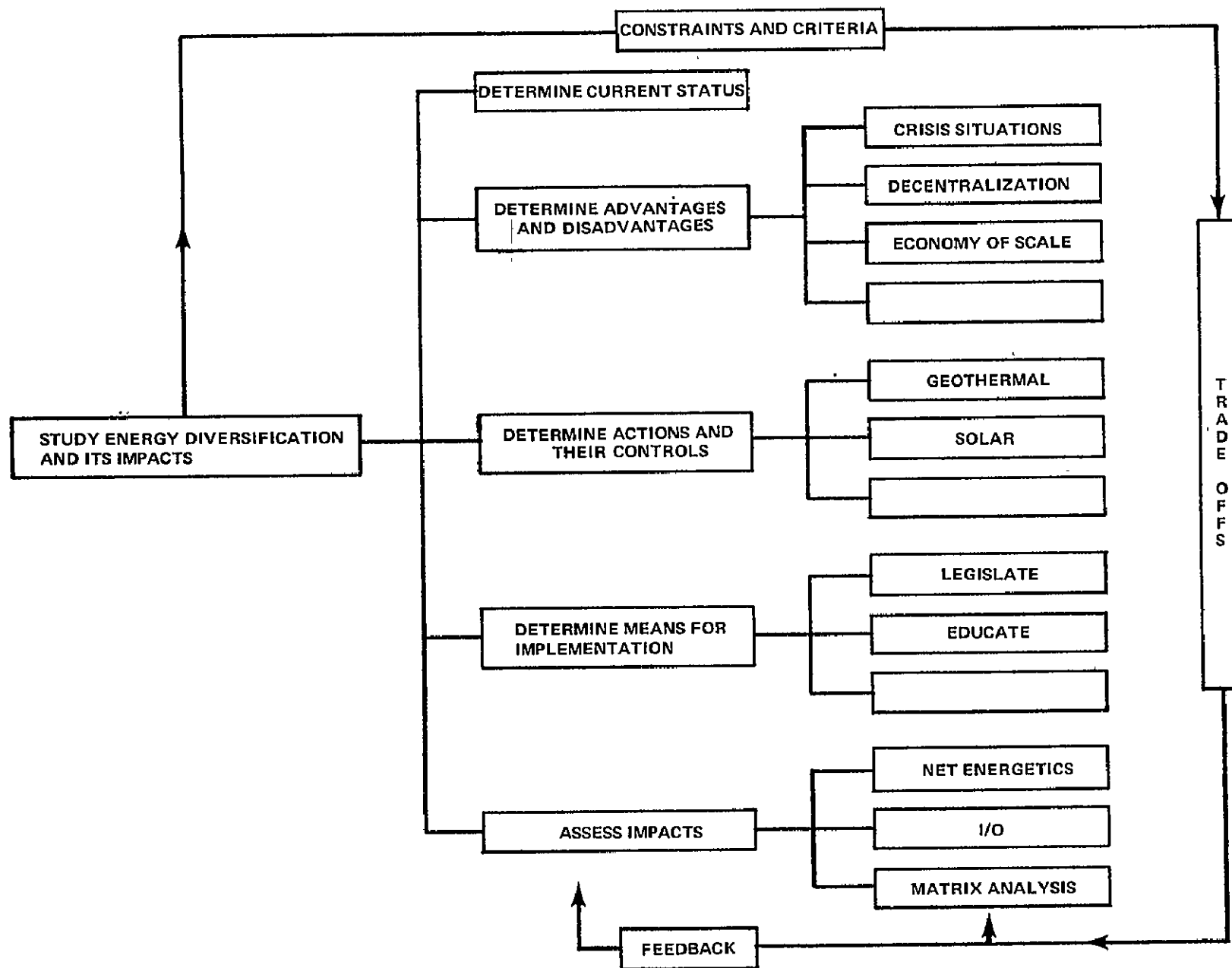


FIGURE 11.2-1. SYSTEMS DIAGRAM FOR DIVERSIFICATION STUDY

Determine diversification actions and their controls

Determine the means for implementing overall diversification

Assess the overall impacts

Each of these requirements is examined in detail in the following sections. The alternative methods for satisfying each requirement are explored in order to allow trade-offs during the assessment stage of the study (see Figure 11.2-1).

### 11.3 ADVANTAGES, CRITERIA, AND CONSTRAINTS

#### 11.3.1 ADVANTAGES

The fundamental justification for an energetic diversification program is reflected in the overall advantages which it offers. As will be seen in the sections below, these advantages are potentially enormous.

##### 11.3.1.1 COMPETITION

A healthy economy presupposes vigorous competition. The diversification program lays a foundation for encouraging competition

between suppliers,

between utilities,

between energy hardware manufacturers, and

between producers of energy using equipment.

It may, in fact, be possible, through increased competitiveness, to effect a reduction in the cost of imported petroleum. This would follow if the world demand for OPEC oil declined, but the potential results may be even more dramatic. A demonstration of the feasibility of a variety of alternate energy technologies could pose a potential economic challenge to OPEC nations, but more important for the near term, it would obviate arguments internal to some OPEC nations that running out of oil is tantamount to running out of energy altogether.



### 11.3.1.2 CRISIS SITUATIONS

A number of crises have arisen within the past few years, and to a lesser extent within the past few decades, because of energy system concentration within the United States. A diminution of the magnitude and frequency of crisis situations is foreseeable as a product of diversification. Problem areas which could be favorably affected by diversification are those developing from:

Industry-wide labor disruptions. A multitude of industries makes it difficult to affect energy supplies nationwide.

Monopolistic practices and pressures. Diverse supplies and suppliers would foster competition.

Foreign embargos and price increases. Self-dependence is possible in the long run.

Shortages of specific fuel types. Shortages would have repercussions, but not of the magnitude we are presently experiencing.

Mechanical breakdowns with system-wide consequences. A complete breakdown in one energy supply would not necessarily affect other supplies.

Unforeseen impediments to technological development. Pursuing a single (or few) promising supply sources might not 'pan out', and would leave us with nothing for the future.

The first three crisis-related advantages listed above are political in nature and generally reflect a decentralization of the power base within the energy arena. The latter two listed advantages are derived from diffused technology. We have experienced breakdowns and blackouts within the past few years which were a consequence of single system complexity; we can expect more. In a similar vein, technological difficulties frequently arise in systems both before (as e.g., in nuclear generation) and after (as e.g., with the Boeing 747) they are put on line. Systems of the future are likely to exhibit similar vicissitudes.

### 11.3.1.3 LOCAL ENERGY PRODUCTION

One of the often overlooked features, which from a variety of perspectives looks extremely exciting, is the potential for utilizing resources proximate to the point at which the energy will be used. At least three consequences of this are readily apparent:

Decreases transportation and transmission distances

Contributes to regional self-sufficiency

Feeds energy dollars back into the local economy

### 11.3.1.4 DECENTRALIZED PLANT LOCATIONS

Extravagant energy-producing schemes envisage massive developments of the resources within a concentrated area. Along with the other difficulties, this will cause rapid and extensive population build-ups within the immediate area and is likely to result in hostility and major resistance among local citizenry. This, in turn, has the potential of impeding the progress of a development. Diversification, because of its emphasis on decentralization, lays a basis for the interruption of this trend.

### 11.3.1.5 LONG RANGE ENERGY POLICY

Historically, little attention has been given to mid-term and far-term energy policy. Many proponents of mono-energy, near-term solutions have effectively shut the door on future alternatives since undue attention to immediate needs can deprive future alternatives of an adequate technological base. In this respect, a program of diversification can enhance the prospects for future energy development and long range energy policy.

### 11.3.1.6 ENVIRONMENTAL OVERLOADS

A reasonable prospect exists for extensive environmental disruptions of a single type from a single energy source. There are very few, if any, energy systems which do not affect flora, fauna, air or water in some detrimental fashion, but by diversifying the nation's energy supplies it may be possible to spread out these effects and thereby reduce the overall magnitude of environmental impacts.

### 11.3.2 MAJOR CRITERIA

There are three important criteria by which a diversification program should be judged:

Encourage the use of a variety of energy systems. Those systems which use energy and those which produce it should be understood as an integrated whole. This does not imply arbitrary diversification, or diversification at any cost; it does entail overcoming major economic constraints.

Encourage the development of non-petroleum sources. This does not mean eliminating petroleum based energy systems, but it does mean using them more selectively.

Tailor an energy source to its use. Some of the factors which need to be considered are thermodynamic, geographic, demographic, biological and meteorological.

Some clarification of this last criterion can be made by way of illustration. Current practice in densely populated municipalities is to locate electrical generating plants at some distance from the city. The low grade waste heat, suitable for space heating, is given up to the environment. In the same municipality, natural gas supplies many customers with a heating fuel. Tailoring a source to its use could avoid this redundancy. By installing the appropriate type of generating system near the consumer, it would be possible to supply him with both electricity and heat recovered from the conversion process.

### 11.3.3 MAJOR CONSTRAINTS

For each alternative approach to diversification there is a spectrum of constraints. It is desirable to introduce an alternative into those situations where the constraints are minimal. Therefore, prudence dictates that it be ascertained what constraints might be encountered before an action is initiated. Most constraints are specific to an action; nevertheless, there are two gross factors which are likely to inhibit any sustained program of diversification or any action which tends to promote diversification

Perceived cost ineffectiveness due to lack of economy of scale. Whether cost effectiveness does in fact prove to be an inhibitory factor is not the whole issue. The important thing is that industry may assume that it is. A great deal of recalcitrance to any kind of change derives from arguments that economic feasibility depends upon extensive and intensive concentration.

Vested interests of energy producers and energy related hardware manufacturers. It is likely, of course, that such industries can participate in, and can be initiators of, diversification. However, conservation industrial inertia would have to be overcome before diversification could be effected.

#### 11.4 CURRENT STATUS AND PREVAILING VIEWS OF DIVERSIFICATION

##### 11.4.1 CURRENT STATUS

The United States is presently in the position of being primarily dependent on one major energy source; approximately 78 percent of our energy consumption is based on domestic and imported petroleum and natural gas. In 1972, nuclear produced 0.6 quads (less than one percent of our national demand of 72 quads), hydropower 2.9 quads (4%), coal 12.6 quads (17%) and crude oil and natural gas 56.1 quads (78%). About 40% of the oil and natural gas is imported today.

In recent times, some of the disadvantages of being so heavily dependent on one kind of energy, especially when a substantial portion of our supply must be imported, have become obvious. The recent perturbation by OPEC created a cascading of negative impacts throughout our economic system. Illustrative of these first, second, third and higher order effects were the disappearance of jobs in automobile manufacturing, steel production and numerous other directly or indirectly oil dependent industries. Agricultural production was threatened because of reduced fertilizer availability, reduced gas for crop drying and insufficient fuel for farm machinery.

The stimulus provided by OPEC has elicited substantial response from our national energy system. Several new institutions have been created to carry out needed research, development, demonstration and administration. The Energy Research and Development Administration (ERDA) was created by Public Law 93-438 (the Energy Reorganization Act of 1974) to gather under its wing most of the federal activity in energy RD&D and to plot the nations future energy research, development and demonstration course. The Federal Energy Administration (FEA) was created to administer and implement the various policies and acts dealing with energy.

Another law was passed in December, 1974, PL 93-577 (the Federal Non-nuclear Energy Research and Development Act of 1974), which constitutes a congressional mandate to explore a diverse array of potential energy sources. Section 3(a) of PL 93-577 states:

"It is the policy of the Congress to develop on an urgent basis the technological capabilities to support the broadest range of energy policy options through conservation and use of domestic resources by socially and environmentally acceptable means."

Section 6 of PL 93-577, along with PL 93-438, requires that ERDA present to the Congress on or before June 30, 1975, with updating thereafter, a comprehensive plan for energy research, development, and demonstration. The first such plan was delivered to Congress by Mr. Seamans on June 28, and is known as ERDA-48. A further discussion of ERDA plans is found in Appendix K.4.

#### 11.4.2 PREVAILING VIEWS OF DIVERSIFICATION

As has been seen recently, society is faced with many problems resulting from an over-dependence on petroleum and natural gas. It is not difficult to find other examples of the dangers of "one-dimensionality" in this complex mass society. Barry Commoner in his book The Closing Circle [Commoner-71] cites several examples of the unpleasant possibilities posed by large scale unimethods of food production in which the natural eco-system is disturbed. He characterizes the large scale use of inorganic nitrogen fertilizers and synthetic pesticides as being like an additive drug -- the more used, the more needed. Sam Love in his article "Short-loop Living" [Love-74] argues the desirability of diversity and decentralization in technological systems. He cautions about getting our systems "overhitched" or "overconnected" in such a way that small disruptions can cascade and multiply through the inter-connecting network so as to ultimately produce larger and more disturbing impacts. Nature, the elements of which are very intimately linked, is protected from catastrophic impacts through damping caused by diversification and decentralization. Man-made tendencies toward simplification of systems create highly linked mono-cultures fraught with possibilities of catastrophe. Schumacher in his book Small Is Beautiful [Schumacher-73] also addresses some of the problems of large "overconnected" industrial entities. Robert Gilpin in his very recent report to Congress, "Technology, Economic Growth, and Industrial Competitiveness" [Gilpin-75], in many ways sounds as though he is an advocate of diversity relative to a public policy climate which would enhance the possibility for technological innovation in civilian industrial technology. He argues that a major problem of

American science and technology has been our past mono-science-technology orientation in which an inordinate share of our total national scientific and technical resources have been devoted to a few areas of "big science and technology", space, defense and atomic energy. We react to crisis situations -- a SPUTNIK produces a crash program to reach the moon, conflict with the USSR produces crash programs in weapons systems, etc. Gilpin likens our present energy problem as another crisis which is again producing a "crash" program with, as he sees it, undue emphasis on a single-energy solution, the breeder reactor. Gilpin argues against these "crash" programs as being very wasteful and of too little breadth.

In situations such as the present energy circumstance, where there are large measures of uncertainty in terms of future energy supplies and end-use conservation measures, Gilpin suggests that in place of "crash" programs of a one-dimensional nature the U. S. should adopt policies and create institutions for implementing these policies so that a diverse array of possibilities are explored by smaller increments. He calls this approach "incrementalism" and suggests that experiments be designed to enable us to purposefully learn at each increment or step and thus reduce the uncertainties and perceive more clearly the desirable directions in which to move our technology.

In view of the many uncertainties associated with both future energy supplies and future end-uses arising out of the recent experience with a mono-energy culture, there is an urgent feeling abroad that public policy makers should give serious and deliberate consideration to the merits of diversification in both supply and end-use conservation measures.

## 11.5 MEANS OF IMPLEMENTATION

The precise vehicles necessary for implementation of a specific action which will contribute to diversification will depend substantially on the action being considered. There are a few rather broad areas in which steps appropriate to any such action can be taken:

Legislation to assist programs and provide incentives

Financing through low-interest loans, government-guaranteed loans, underwriting pilot projects, and indirectly by providing energy price guarantees

Tax incentives to industries and individuals which develop or install equipment and systems which contribute to diversification

Education programs to develop interests, to emphasize the magnitude of our energy dilemma, and to provide information about our alternatives

Technological information in a cogent format to interested parties to provide design parameters, cost data and information about difficulties which may be encountered

All of the above steps have been suggested as valuable tools in the implementation of new energy sources. However, at present these steps have not been applied to the range of possible energy sources mentioned in the next section (11.6). Only after an overall diversification plan has been decided on can the above steps be used to produce the desired energy source mix. A 'helter-skelter' application of the implementation steps would lead both to confusion and redundancy. Careful attention must be given to integration and optimization of diversified systems.

## 11.6 ACTIONS

The specific set of energy systems which make up a program of diversification should include the following:

Coal

Oil

Natural gas

Oil shale

Biomass

Waste

Nuclear fission

Nuclear fusion

Integrated Systems

Photovoltaic

Solar Thermal

Geothermal

Hydro-electric

Thermal gradients

Solar heating/cooling

Wind

The aggressive pursuit of these alternatives, each of which is discussed briefly in Appendix K.1, is being undertaken by ERDA [ERDA-48], reflecting the intent of the Non-Nuclear Energy Research and Development Act. [PL-93-577]

#### 11.7 ASSESSMENTS

To decide the feasibility of an across-the-board diversification program, a systematic study needs to be undertaken involving each proposed diversification energy action. The first step in such a study is to determine the requirements of each of the alternative energy systems which make up diversification. The major requirements are:

Capital investment

Maintenance

Availability and location of source supply

Manpower

Materials

Water

Land use

Studying each of these requirements entails substantial amounts of research, research which could be conducted within the framework of an overall energy program. Lacking this, it is still possible to outline a format for the task which needs to be undertaken. The following material is an illustration of an analysis of diversification in energy supply with an emphasis on impact assessment relative to a major constraint, water requirements.



### Outline of Example Assessment

By selecting the water requirement as a subject of investigation, it becomes obvious that several questions need to be answered:

Which systems are water intensive, that is, require vast amounts of water, the unavailability of which would jeopardize their development?

What are the geographic locations most suitable for each system?

What are the regions in which water supply is likely to be problematic?

The next question which needs to be answered depends upon the answers to the first three:

Which alternative water intensive systems must be located in water scarce regions?

The results of such an analysis reveal that the water requirements of exactly three systems:

Coal, located in the Missouri Basin, Upper Colorado Basin, and Lower Colorado and Rio Grande areas

Oil shale, located in the Upper Colorado Basin, and

Solar central generation, located in Arizona and New Mexico need further investigation (See Appendix K.2).

There is one final question which ought not be overlooked. That is,

Is there any conflict between the water requirements of coal, shale, and solar?

The study of this subject led to two observations:

There is a potential conflict between coal in northern New Mexico and solar in southern New Mexico.

There is a distinct potential for conflict between coal and shale in the Upper Colorado Basin.

### Conclusions of Example Assessment

On the basis of information available at present, several tentative conclusions are suggested (See Appendix K.3):

Coal located in the Missouri Basin could be converted to synthetic fuels without creating major water problems.

Coal resources located in the Colorado Basins could be developed in moderate amounts, but liquefaction or gasification seems to be ruled out at this time.

Oil shale can be processed without resulting in major conflict with coal or impacting on existing water resources.

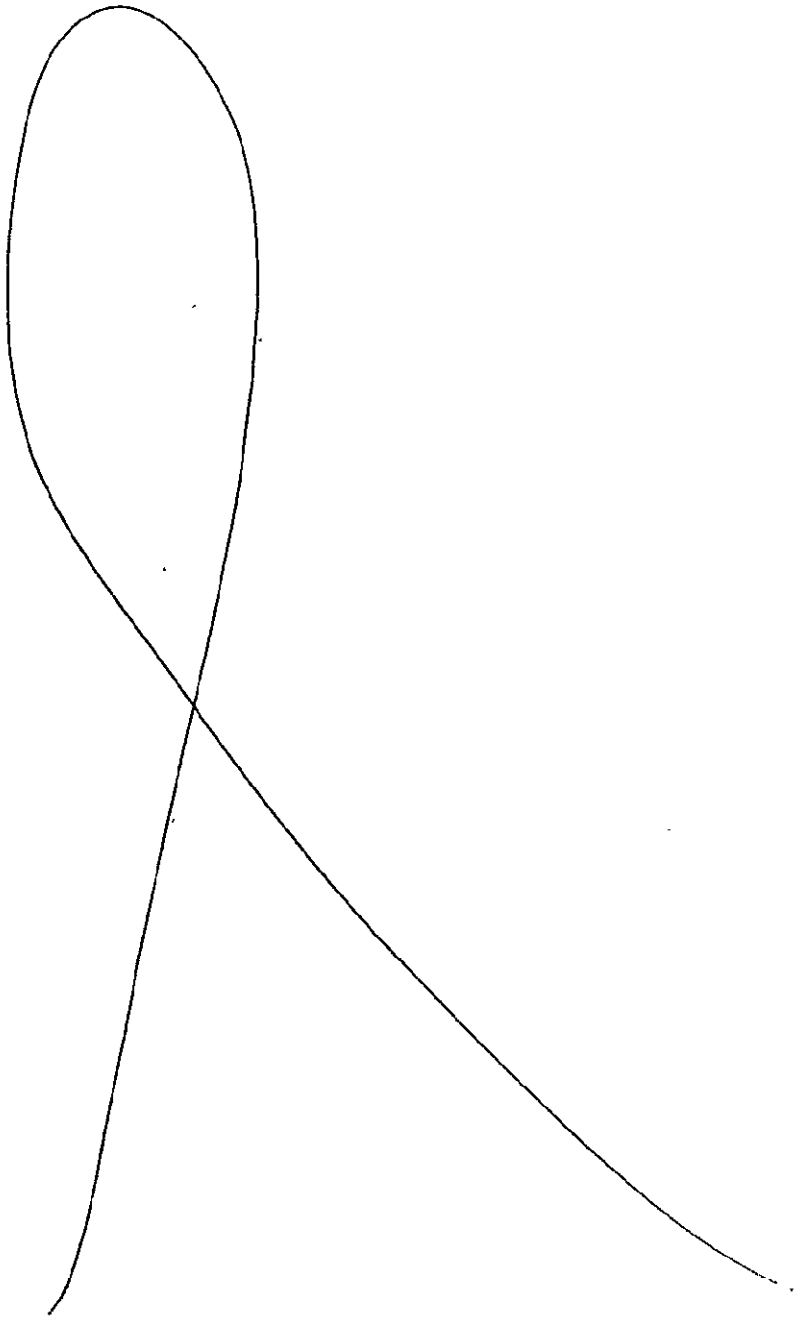
Developing the solar potentials of Arizona and New Mexico is possible without degrading or reducing the volume of water available.

Proposals to augment the water resources of any region need to be analyzed in greater depth.

Further investigation of diversification will entail not only more intensive evaluation of water requirements, but a detailed analysis of other requirements as well. Final conclusions cannot be drawn on the basis of capital costs alone; likewise, resolution of the water problems is not the only basis of decision. Solution of the water problems may result in systems requiring far more capital than investors are willing to supply. Final decisions will ultimately depend upon trade-offs made as a result of evaluating requirements and the alternative ways of satisfying these requirements. This is the intent of the systems method.

### Net Energetics Assessment

Another method of assessment is to calculate the energy "return" on the energy "invested" to a potential energy source in order to bring it on-line. Net energetics shows how the rate of energy return can be calculated. An example assessment for a heliostat solar plant is shown in Appendix C.4.



## CHAPTER 12. CITIZENS' ACTIONS

Citizens are consumers; and in such a role they are a vital cog in the energy machine. Consuming takes energy for direct actions such as traveling to work, going on vacation, using lights and appliances, and cooking. It also takes energy indirectly in producing consumer goods and providing an existence that is felt to be viable. In short, citizens use energy and they also have the potential to save energy. In fact, they must conserve energy if the nation is serious in its attempt to reduce foreign oil imports. But the task may not be easy. The majority of the seminar speakers for the 1975 Summer Faculty Fellowship Program, who incidentally were a representative cross-section of upper class Middle America, were quite sympathetic with energy conservation and the need to save. Hence, the need for a qualifying note--they were sympathetic, but only if it didn't mean a change in their life style. Is this possible? Can we, as citizens, indeed save significant amounts of energy without disrupting a consumptive life style?

This chapter of the report addresses the above question, and hopefully provides some answers or alternatives. In confronting the problem, a number of considerations must be examined closely; for example, personal consumption patterns, the effects of the embargo, conservation actions, barriers to savings, etc. Only in this type of framework can one expect to present the true picture of citizens' actions--past, present, and future.

As we shall see, there are ways that citizens can save energy, individually and in groups. The potential savings are significant, but the actual savings achieved may be quite small. The citizen needs to be motivated to save and to believe in a conservation ethic. Developing such an ethic is difficult, and perhaps not responsive to the shotgun approach now being attempted. Perhaps a future synopsis of the present situation will reveal that Americans failed in their post embargo attempt to conserve, and that the true course of action should have been one of synthesizing new societal structures that provide the maximum evolution of culture within the limitations of scarce energy resources.

## 12.1. BACKGROUND

### 12.1.1. DEFINITION

During this discussion, citizens' actions are considered to be those implemented by the citizen to conserve energy, and they include such things as individual changes in life style (walking to work, carpooling, turning back thermostat), group actions that include a city's "save-a-watt" program, and citizens' groups participation at the local level.

### 12.1.2. ENERGY AND THE EVOLUTION OF CULTURE

Before one looks at citizens' actions and attempts an assessment, it is necessary to speak of consumption patterns. In other words, how and to what extent does the citizen consume energy? Do Americans consume more than others? Did this generation consume more than the last? Perhaps still yet a more basic question must be asked. Why the need for energy in the first case? How does it change our life or make us better people? As background, consider that man as an animal species, and, consequently, culture as a whole, is dependent upon the material and mechanical means of adjusting to the natural environment. Man must have food and be protected from the elements. And he must defend himself from his enemies. These three things he must do if he is to continue to live, and these objectives are attained only by technological means. One might say then that the technological system is both primary and basic in importance; all human life and culture rest and depend upon it. Therefore the evolution of culture, meaning the production of goods and of life's comforts, is directly related to the amount of energy harnessed and put to work in man's service. Only by technological means is energy harnessed. Tools of one kind or another accomplish this, but some are more efficient than others.

The point of the discussion is that the amount of food, clothing, or other goods produced in a society depends on (1) the amount of energy harnessed per year and (2) the efficiency of the technological means with which energy is harnessed and put to work. In other words, culture evolves as the amount of energy harnessed per capita per year is increased, or as the efficiency of the instrumental means of putting the energy to work is increased.

In a historical perspective, the nation is at a crossroads. Further advances in culture, or perhaps even maintaining a status quo, depends on increasing our energy supply or increasing the efficiency of the technological processes involved. In a sense both of these factors are linked to the consumer. If less is consumed, the supply is less limited. Hence, actions such as adding insulation to homes increases the efficiency of the energy usage process and decreases consumption.

Table 12.1.2-1 compares the consumption of energy in our present culture with that of previous societies. It illustrates vividly the present dilemma: modern man is consuming energy at an astonishing rate -- and in the process is depleting finite resources.

### 12.1.3. PERSONAL CONSUMPTION PATTERNS

In terms of energy use per capita, the average United States citizen today is the greatest energy user the world has ever known. Figure 12.1.3-1 shows an annual comparison of per capita energy use among various countries. The standard of living in the United States has reached a point where the per capita use of energy is near 400 million BTU per year. This, of course, includes all the energy used to produce the goods and services consumed by the average citizen.

Between 1950 and 1973 the U. S. population grew from 151 million to 206 million people, an increase of approximately one-third. During this time, the amount of energy consumed by this population doubled. Today, U. S. per capita energy use is six times the average for the rest of the world. Our gross energy consumption has also increased at an average approval rate of 3.1 percent between 1947 and 1971. During the 1965-1970 period a 4.8 percent growth rate was experienced.

The energy growth curve in Figure 12.1.3-2, coupled with the above figures should leave doubt of where we stand as energy consumers.

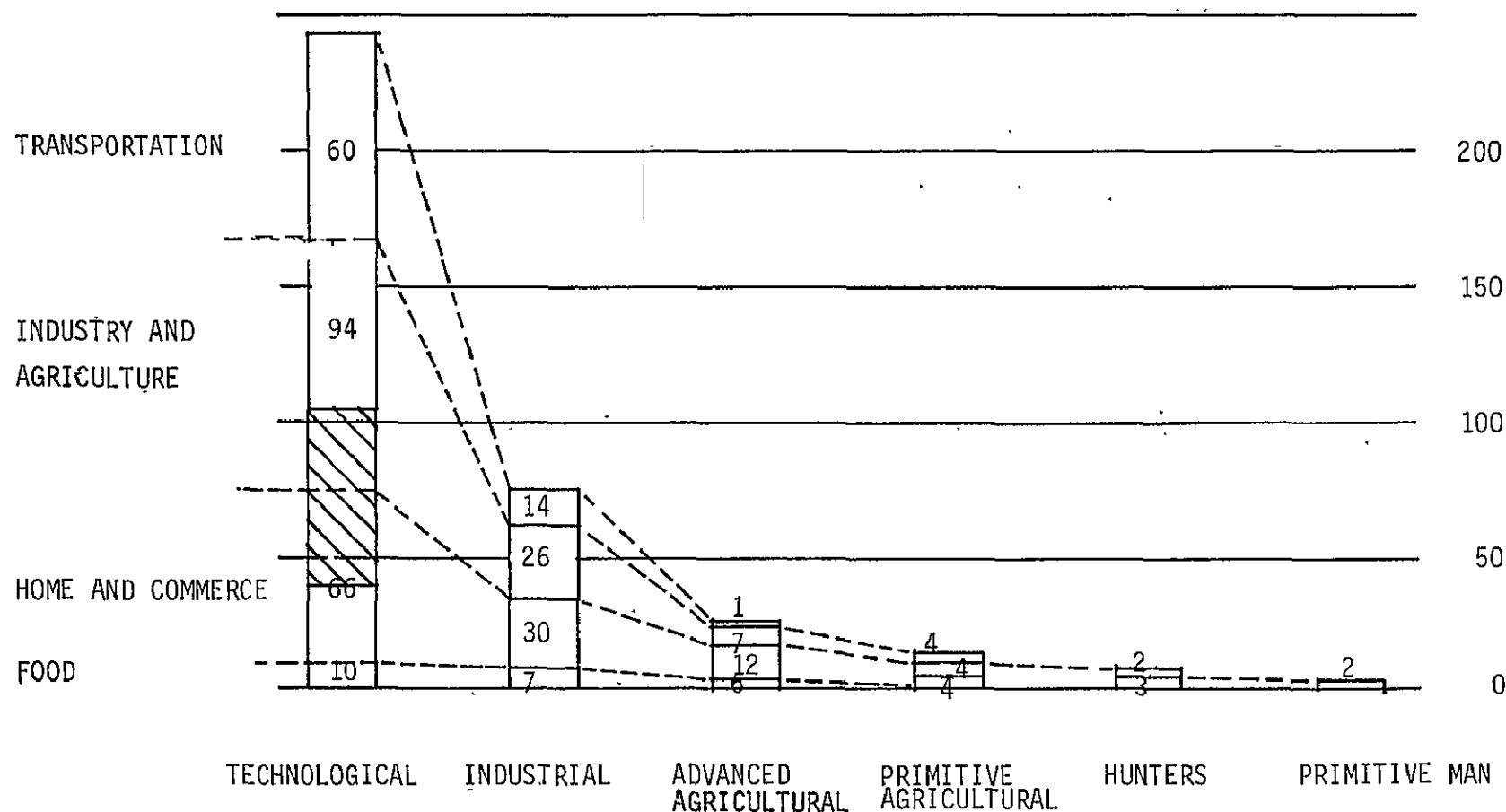
### 12.1.4. SUBSTITUTING ENERGY FOR LABOR

As we examine the past consumption patterns in the United States, it readily becomes apparent that there has been a potent increase the last 25 years in energy demand. What has taken place in our society that accounts for this pattern? Hannon (SCI) cites examples of increasing energy and decreasing labor utilization in a number of industries [SCI-75,95]. For example, the system that produces beverages has been shown to be more labor demanding and less energy demanding if the beverages were delivered in refillable rather than throwaway containers.

Steinhart and Steinhart note that the proportion of people engaged in farming halved between 1920 and 1950 and then halved again by 1962. In contrast, total use of energy in the United States food system grew from  $685.5 \times 10^{12}$  kcal/year in 1940 to  $2172 \times 10^{12}$  in 1970. Other examples could be cited for the replacement of labor by energy [SCI-74,307].

Due to past abundant "cheap" energy, industry has become energy intensive. In other words, in the past, economics has overruled energy conservation. Likewise, modes of transportation have become less efficient--in part because of larger engines, but more recently due to modifications required to meet pollution standards. In the last several years,

TABLE 12.1.2-1. DAILY PER CAPITA CONSUMPTION (1,000 KILOCALORIES)



Primitive man (East Africa about 1,000,000 years ago) without the use of fire had only the energy of the food he ate. Hunting man (Europe about 100,000 years ago) had more food and also burned wood for heat and cooking. Primitive agricultural man (Fertile Crescent in 5000 B.C.) was growing crops and had gained animal energy. Advanced agricultural man (northwestern Europe in A.D. 1400) had some coal for heating, some water power and wind power and animal transport. Industrial man (in England in 1875) had the steam engine. In 1970, technological man (in the U. S.) consumer 230,000 kilocalories per day, much of it in form of electricity (hatched area).

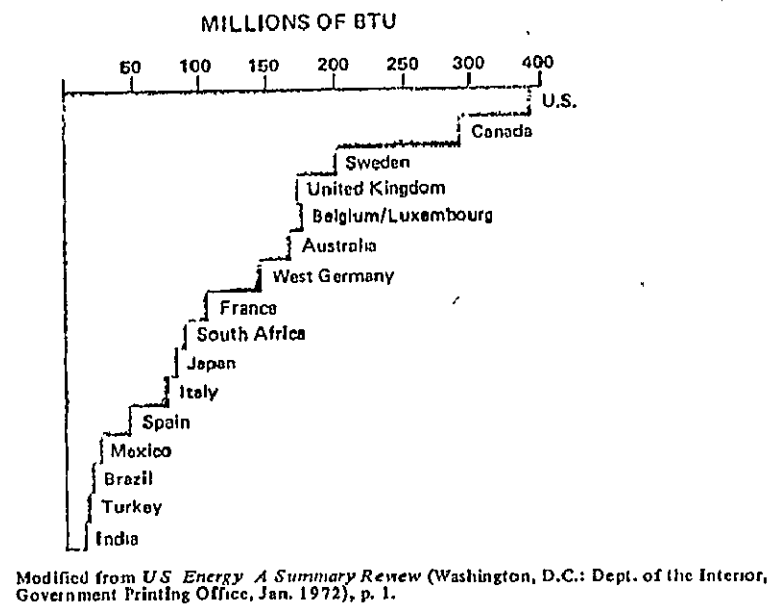


FIGURE 12.1.3-1. PER CAPITAL ENERGY USE, 1968  
[ENERGY-75, 34]

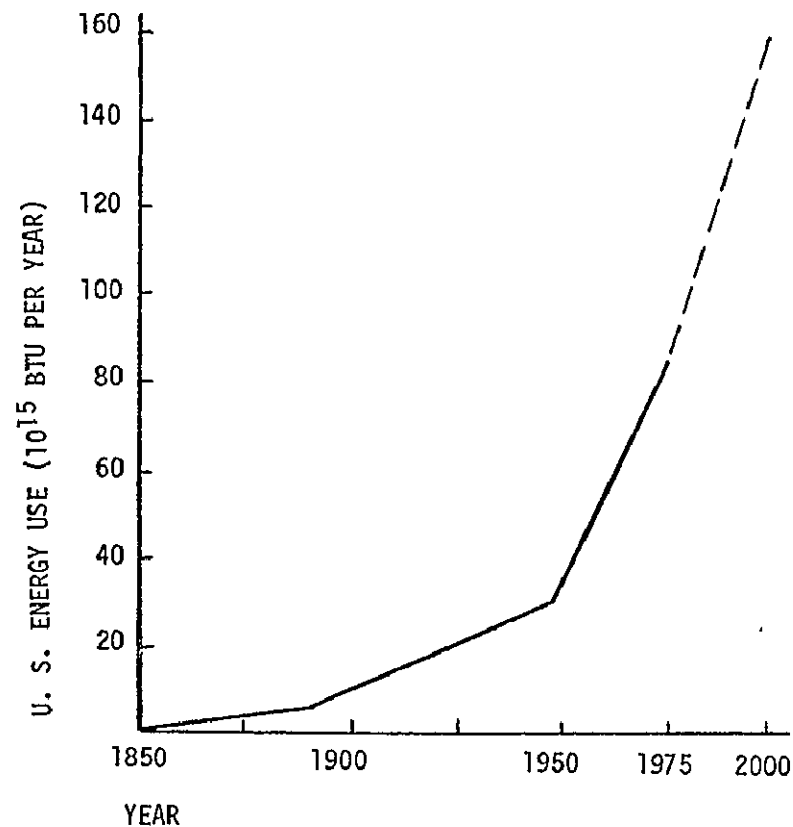


FIGURE 12.1.3-2. PAST AND FUTURE ENERGY DEMANDS IN THE UNITED STATES  
[ENERGY-75,11]



many changes in society have taken place. These changes account for our radical consumption patterns. The citizen, in terms of personal lifestyle changes, has certainly contributed to this trend.

## 12.2 OIL EMBARGO AND THE CONSUMER

The total impact of the Organization of Petroleum Exporting Countries (OPEC) oil embargo, as contrasted with the impacts of higher energy prices and energy shortages, is subtle and difficult to separate. However, estimates indicate that the output of the economy fell in the first quarter of 1974 by 10 to 20 billion dollars as a result of the embargo. Unemployment effects were estimated to be 0.5 percent of the civilian labor force or about a 500,000 people reduction. Energy prices during the embargo were responsible for at least 30 percent of the increase in the Consumer Price Index [PI-74-1,288]. As a result, Gross National Product fell at an annual rate of 6.3 percent during the first quarter of 1974. In addition, personal consumption expenditures fell 4.8 percent in the fourth quarter of 1973 and 2.7 percent in first quarter of 1974. Ninety-six percent of the decline in the first quarter of 1974 resulted from curtailed demand for auto and auto parts and energy.

The above figures relate an overview of the economic impacts of the embargo. A close analysis of changes in consumption patterns relate the following:

Household travel - There was a drop in the number of trips made during the oil embargo, especially those for social, recreational and dining purposes. Besides work related trips, the reductions were due to difficulty and uncertainty in obtaining gasoline.

Household heating - During the embargo, households responded admirably to government requests to reduce temperature levels. The average level of household temperature during 1973-74 was 68 degrees, a two degree reduction from the previous year's average.

Use of electricity - The continuous National Survey showed an increase from 29 percent of those respondents reporting a reduction of major appliances during November to about 48 percent at the end of February.

The above data indicate that there was significant consumer response to the oil embargo. Perhaps the dilemma results from post embargo events. Since that time, there has been a significant increase in consumption at all levels. Even though the rate of gasoline consumption had slumped by 1.9 per cent annually in the last two years, it has now climbed back to near pre-embargo levels in spite of a national July, 1975 average of 58.7 cents per gallon. In other words, Americans are travelling at a greater pace than ever before, maybe in anticipation of even higher gasoline cost during next summer's vacation period. Even though polls indicate Americans are trying to accomplish energy savings, there is no substantial evidence to support this fact. Perhaps the capital saved from one conservation action is being reinvested in another mode of energy consumption..

### 12.3. BARRIERS TO SAVINGS

A variety of barriers to savings can be identified. A few of these are discussed briefly in this section.

#### 12.3.1. CREDIBILITY GAP

Many people have indicated that perhaps one of the large barriers to obtaining significant savings in energy consumption is the credibility gap between producers and consumers. For example, the widely voiced opinion that the spiraling cost of gasoline is the result of a rip-off by the oil companies certainly does not enhance the conservation ethic. On the other hand, a recently conducted energy survey [Vanston - 75] indicated that 100% of the people surveyed believed that there really is an energy problem and 76% indicated that they thought the consumer was the problem. One would suppose that a belief in the validity of the energy problem would lead to a reduction in consumption. However, the fact that consumption levels are once again approaching historical growth in spite of increasing energy costs makes one feel that either people really don't believe that the energy problem is serious enough for them to reduce consumption or they don't believe that there really is an energy problem.

#### 12.3.2. CONSUMPTIVE LIFESTYLES

The lifestyles of American households are directly reflected by household energy users. For the past 25 years, these developing lifestyles have been based on rising real incomes and stable or falling energy costs. Now that the tide has turned, rising energy costs must have an effect on lifestyles. One area that must be examined in assessing the impacts of rising energy costs on lifestyles is the percentage of household income devoted to energy. As can be seen from Table 12.3.2-1, energy consumption rises with increasing income, but the differences in energy consumption are less than proportional to differences in income. For example, in 1973, a household with \$2,500 income consumed only two-thirds of the energy of a household with an income of \$8,000 and approximately half the amount of the \$14,000 household.

TABLE 12.3.2-1. ENERGY EXPENDITURES AND CONSUMPTION BY INCOME CLASS, 1973  
 adapted from [Ford-74,118])

Income category	Average energy expenditure per household	Total BTU's consumed (in millions)	Percent of total Income spent on energy
range income:			
\$2,500-----	\$379	207	15.2
\$8,000-----	572	294	7.2
\$14,000-----	832	403	5.9
\$24,500-----	994	478	4.1

Another important consideration, however, is the percentages of total annual income spent on energy. As can be seen from Table 12.3.2-1, this percentage is significantly higher for low income families. Obviously, this means that rising fuel costs will impact the poor much harder.

Some of the areas in which lifestyles may change in response to increasing energy costs are location and types of family dwellings. For example, multi-family dwellings generally consume less energy than single family dwellings. Energy for transportation is basically determined by the spatial relationship of houses to jobs and shopping centers and to the density of development. In fact, one study estimated that for a given population mix, the energy consumption for heating and transportation in an unplanned community of single family homes is 44% greater than that associated with a planned community of higher density and containing substantial numbers of high rise and garden apartments and town houses. [Hearings-75, 262]

Obvious impacts on lifestyles in the area of transportation can be anticipated. Air travel may decline as prices increase. Consumers will be faced with the choice of paying higher prices or reducing consumption by driving less or small cars.

### 12.3.3. INVERTED RATE STRUCTURE

The existing utility rate structure obviously does not encourage conservation -- the more you use, the cheaper the rate. Perhaps significant savings might result if the rate structure were revised so that the rate for consumption above a specified level was considered higher. In this case, consumers might watch their meter each month in an attempt to keep their consumption at a specified level.

### 12.3.4. FUEL COSTS

On the other hand, if fuel costs were to decline (suppose the knee-deeper theory is correct), consumption would probably return to the exponential growth curves prevalent prior to the embargo. Thus, low fuel costs are an obvious barrier to energy conservation.

### 12.3.5. INITIAL COSTS COMPARED TO LIFE CYCLE COSTS

Consumer buying patterns are decidedly affected by initial costs. A major consideration of one item over another is the initial costs of each. An appliance that is energy efficient, but costs more, is difficult to market simply because the consumer is not interested in or is unaware of life-cycle costing. Educating the consumer to the advantage of life-cycle costing may be a monumental task, but one that is worthwhile from a conservation point of view. It has been estimated that six additional inches of ceiling insulation will yield a winter dollar savings of \$180 to \$220 and a winter fuel savings of 515 to 635 gallons. Recovering costs of the initial investment requires approximately one year. However, it is still difficult to motivate people to purchase insulation because of the high initial costs.

## 12.4 INCENTIVES TO SAVE

A variety of incentives for saving energy have been identified. Several of these are mentioned in the following sub sections.

### 12.4.1 TIME TO DEVELOP ALTERNATIVES

One very important aspect of citizens' actions is that they represent a viable means of bridging the short term period until alternate resources become available. It is the opinion of many experts that 10-15 years will be needed to perfect the technologies and build the facilities required to make the widespread use of future resources possible.

### 12.4.2 SCARCITY OF FUELS

One obvious reason for conserving fossil fuels is to extend the lifetime of the finite supplies of these fuels so that they will continue to be available for unique uses for which they are suited. Discussions of conservation often included substitution as one category. In this case, substitution can mean substituting coal or uranium for oil and natural gas. This substitution conserves supplies of oil and natural gas, but it is not conservation in terms of reducing consumption of fuel. Another type of substitution might be a substitution for end products or substitution of materials during manufacturing. Both of these areas may offer potential savings; for example, substitution of aluminum or plastic in cars may reduce fuel consumption in the form of gasoline as well as fuel consumption reduction in the manufacturing process.

### 12.4.3 REDUCTION OF DEPENDENCE ON IMPORTS

Reducing consumption of oil and natural gas would result in a decline in imports of these expensive fossil fuels. As the price of these fuels continues to climb (as a result of deregulation of gas and decontrol of oil price, along with OPEC price increase), consumers confronted with the alternatives of spending a greater percentage of their income for energy or decreasing consumption in order to save money may decide to opt for using less energy. Reducing consumption of oil and gas obviously would help to alleviate the balance of payments problem that the country faces when importing large quantities of oil.

### 12.4.4 DECREASING ENVIRONMENTAL POLLUTION

Another problem emerging from the energy crisis is the apparent conflict between environmental protection and energy production. For example, burning coal creates numerous environmental problems, including air pollution

resulting from the release of sulfur dioxide and particulates. It follows, then, that a reduction in the use of fossil fuels will lead to decreases in air pollutants. Reducing consumption would not only help in reducing the amount of particulates, but would also reduce the amount of carbon dioxide released to the atmosphere. The exact relationship between these two pollutants and their effect on world climate has been the subject of many discussions. [Rotty-75] Reducing consumption could also lead to a reduction in the heat released in the combustion process. The effect of waste heat on world climate is also currently being debated. [Rotty-75] In any case, it appears that a reduction in consumption that may help in alleviating some environmental problems facing the nation and the world.

## 12.5 PRESENT APPROACHES

Actions by citizens to conserve energy may be individual actions or group actions. This section presents an overview of various actions -- group and individual -- that fall under the classification of citizens' actions. The list is not meant to be comprehensive, but only to represent the types of actions which may result in energy savings by the citizen.

Suggested individual actions:

### Transportation Sector

- travel by railroad or bus instead of car
- walk rather than drive
- drive at posted speed limits or lower
- keep car properly tuned
- keep car as long as possible
- buy only one car per family
- take short recreational trips rather than long
- carpool as much as possible
- try to live close to work
- combine shopping trips
- promote door-to-door delivery service
- promote local stores within walking distance
- ban parking in downtown parking areas
- drive small efficient cars

### Residential Sector

- set thermostat back to 68°F (day)
- set water heater back to 120°F
- set air conditioner thermostat up to 78°F
- set 8-hour thermostat back to 60°F (night)
- reduce bathing water consumption
- turn off pilot lights in gas furnaces
- retrofit homes by adding insulation, storm windows and doors, and caulking
- keep furnace and air conditioner properly tuned
- install heat pumps to replace resistance heating where applicable
- reduce lighting levels to a minimum acceptable level
- install restricted flow shower heads
- buy the most efficient appliances regardless of initial cost
- turn off lights when leaving a room
- use lower light intensities in rooms
- use natural light whenever possible
- carefully use electric stoves (turn off heat before finishing)
- avoid opening refrigerators unnecessarily

Individual actions are numerous and the potential of many such actions has been discussed elsewhere in the ECASTAR report. Before encouraging such actions however, a comprehensive assessment within the systems approach framework should be undertaken to determine the overall feasibility of the actions. Such an assessment should identify the requirements for, the alternatives to, and the impacts of such actions. For example, installing insulation in certain areas of the country may provide minimum energy savings at the expense of a considerable investment of energy and capital in producing

the insulation. Homeowners should be aware that the energy saved by adding windows to take advantage of natural lighting would likely be offset by heat infiltration and its impact on cooling loads. Proper assessment should identify problems such as the above. Only after such an assessment should a citizens group or an agency promote such actions.

#### Group Actions:

The following is a selective list of programs that require citizen involvement and are currently being implemented at local, state, or national levels.

#### Energy Management Plans

Under the auspices of the General Services Administration, massive savings were accomplished at government centers throughout the country. Marshall Space Flight Center, Huntsville, Alabama, was involved in such a program and achieved a 21.4% total annual energy savings. Actions specifically involving workers included MSFC involvement in the DOT computerized carpool matching system, reserved parking for carpools, and encouragement of general conservation practices by the employees.

#### Citizens Actions Committees

Organized community leaders have been working in pilot projects to promote energy conservation. Committees have been established in 11 states by Mrs. Virginia Garrett, a dynamic Montgomery, Alabama, community leader. Emphasis in the projects is placed on promoting conservation actions by education in schools, businesses, industries, homes and public buildings, and by campaigns to ride-the-bus, build and use bike trails, and car-pooling. [Garrett-75]

#### Project Conserve -- A Pilot Project in Homeowner Energy Conservation

Project Conserve was an information-incentive program to encourage homeowners to voluntarily enhance the thermal efficiency of their homes. Data supplied by the homeowners on a questionnaire are processed by computer to yield cost and savings of energy consuming retrofit actions -- weather stripping/caulking, or thermostat setback. In this particular study, 21% of the homeowners securing the questionnaire completed and returned it. These homeowners were sent the computer report, and 48% indicated that they intended to take at least one of the actions described.



Kill-a-watt -- A Three-Part Program by Department of Lighting --  
City of Seattle.

One major emphasis is undertaking a comprehensive active role in showing residential, commercial, and industrial customers how they can eliminate waste and use electrical energy wisely. The Department of lighting sends out specialist teams to homes, businesses, institutions, and industries to work directly with them in saving energy. A citizens' advisory committee worked with the program to provide an outside, objective view of utility operations and to develop future procedures and policies.

## 12.6 SAVINGS -- POTENTIAL AND PROGRAMS

A look at the variety of programs in consumer education currently being sponsored by FEA and other agencies indicates that this is an area that offers significant potential savings. However, the success of a particular program will be hard to measure. In fact, the success of any proposed conservation action will depend on the cooperation and participation of the individuals involved. To date, the result has not been encouraging. Although significant savings were obtained during the energy crisis, the nation as a whole did not rally around the flag. There are many conjectures as to why consumers are not conserving:

They don't believe there is an energy problem.

They think it is a rip-off by the oil companies.

They are concerned that rationing may be an action in the future, (so they are hoarding, or they are using all the energy they can while it is available).

Energy is not expensive enough to force conservation.

These are only a few of the suggested reasons given to try to explain why the American consumer has not accomplished a significant savings. As stated previously, the potential for savings is significant, but the question is "How does one enlist the participation and cooperation of the consumer?" Several alternatives are discussed in the following sections.

### 12.6.1 MANDATING CONSERVATION ACTION

One may force participation in conservation by enacting laws to accomplish some of the following kinds of actions:

Establish differential rate structures so that the base rate may be relatively inexpensive, but additional consumption is priced significantly higher. This escalator clause should encourage consumers to watch their meters and reduce consumption to stay within the base rate.

Force consumers to drive smaller cars or drive less by restricting gasoline consumption.

Encourage support of public transit by restricting parking.

Prohibit further use of ornamental gas lights and pilot lights.

An alternative to mandating conservation is to educate the consumer -- instill the conservation ethic in all Americans.

#### 12.6.2 CONSUMER EDUCATION -- THE CONSERVATION ETHIC

Both FEA and ERDA currently have a variety of programs for educating the consumer. For example, FEA will initiate a series of Citizens Training Institutes this fall and follow up on the Project Conserve Program. Bolton Institute has a contract for working with school age children and teachers. ERDA also has consumer education programs, but ERDA is more concerned with the technological side of the problem. Perhaps ERDA could attempt to promote the role of conservation through science fair-type projects. The response to the Sputnik challenge was overwhelming. The same level of interest might be kindled by conservation projects.

Other areas of education that could be explored include education of energy consultants (analogous to county agents or home economists). These energy consultants would visit individual homes and advise the home-owner in reducing consumption by changing lifestyles, retrofitting, etc.

Funding should be made available for courses in energy conservation in continuing education programs throughout the country. Colleges and universities are fertile grounds for educating consumers, if the teachers are enthusiastic about the topic. The impacts of educating students should be evident within a short time because they will be buying homes and appliances in the near term. In addition to courses, summer workshops on energy conservation for teachers should be promoted. In fact, the systems approach might be adapted to such a study in order to illustrate the method for attacking a large problem.

#### 12.6.3 CHANGING LIFESTYLES

Any comprehensive proposal for dealing with energy conservation will necessarily include actions that would result in changing the lifestyles of Americans. For example, the minivan concept and other carpooling ideas

are actions that save energy but require a commitment on the part of the individuals involved. Most people do not want to give up the convenience and solitude of driving their own car to work. To them, joining a car-pool means a change in their lifestyle. Depending upon public transportation would be an even greater change for many people.

One idea that has been suggested for saving some of the energy expended by housewives in shopping is to resurrect delivery service. This action needs to be examined to assure that its implementation would result in energy savings. If the assessments were positive, stores would have to be encouraged to provide this type of service.

Inspection of the preceding discussions on various consumer actions reveals that the savings to be obtained from these actions require little or no technical innovations. In fact, the largest savings in the consumer area could be obtained in the near term. This reduction in consumption might buy the nation the time it needs to develop alternative forms of energy. However, the potential savings may never be realized unless consumers become aware of the problem and are willing to change their consumption patterns.

## 12.7 CONCLUSION AND RECOMMENDATIONS

Several major ideas on energy conservation have been expressed by the group repeatedly. After using the systems approach, the group feels that a conservation action should be proposed or mandated only after it is properly assessed; i.e., a systematic study should be made to determine the requirements for, the alternatives to, and the impacts of implementing such an action. For example, consider that a consumer parks the car and rides his bicycle to work every day. Obviously, he is saving energy in the form of gasoline. On the other hand, a more detailed assessment should ask the question, "What does he do with the money he saves?" Whether he saves it or spends it, energy will be required to provide for the freed monies. If the consumer is armed with specific information, he can purposefully direct the money saved by bicycling so that he does realize a net savings in energy. The point is that he must be made aware of the possible impacts of not spending the savings wisely. [SCI-75-1]

A second point concerns the comment made by many that the only way to have people conserve is to let prices rise. In other words, if gasoline prices rise sufficiently high, people will no longer be waiting in line to purchase this expensive commodity. However, before deciding to decontrol the price of oil and gas, one should try to assess the various impacts of such an action. For example, rising costs may indeed reduce consumption, but what about the effect on the poor? Since the percentage of their income spent on energy is greater, they are impacted much harder. In addition, there is probably very little they can do about reducing their consumption. Viable alternatives for dealing with the poor would need to be identified and assessed before the action is taken.

## CHAPTER 13. ECASTAR SUMMARY AND RECOMMENDATIONS

ECASTAR presents a methodology for a systems approach to energy conservation. In order to develop a systems methodology, it was imperative that a definition of conservation be found. In the essence of the systems approach, it was not possible to completely define conservation until the constraints and criteria that bound the energy problem had been identified. The group agreed to depict conservation as the result of any action that improves the energy situation of the U. S. in the present and near future. The set of actions that satisfy this broad characterization would, of course, be narrowed down by the constraints and criteria applied by the specific decision-maker. This report contains a discussion of the choice of relevant constraints and criteria and their application. Among the most important are the present (capitalistic) structure of the American economy, the lead times necessary for implementation of relevant technologies, and the desire of most policymakers to maintain a reasonable standard of living with a reasonable amount of invulnerability to foreign discretion. An "energy performance criterion" is discussed and to some extent applied to conservation actions. It represents a basic choice between "net economics" and "net energetics" when a difference exists. Although many of the constraints and criteria may be quantified, it must be emphasized that subjective judgments remain. Ascertaining the value of certain actions to the American public has always presented a policy dilemma.

From Project Independence, the group inherited the notion that there are three basic modes of conservation:

To increase efficiency in energy use.

To curtail energy use.

To substitute for scarce fuels.

These are not thought to be mutually exclusive. The third may not intuitively appear to be conservation as total energy use may, in fact, go up! This serves to emphasize that conservation depends on the criteria we impose on these actions.

The objective of the design group was the assessment of the potential and impact of conservation actions in the United States. The organization of the group to accomplish the objective fell into two categories:

Assessment of conservation actions by sectors of the economy.

Assessment of conservation actions related to various conservation strategies.

The U. S. economy was divided into four sectors -- energy industry, industry, residential/commercial, and transportation. Each sector was analyzed for conservation actions and their impacts. The sector analysis was characterized as the systems design or constructive phase.

Parallel to this inductive effort was the attempt to broaden the sector orientation by assessing the conservation potential and impact of three strategies facing the nation today. These strategies are diversification, electrification, and national (legislative) energy conservation. The three strategies selected for assessment represent the adjudged most probable and most thoroughly studied directions in which the U. S. energy system may go. All three are high technology, high government involvement methods for achieving energy growth and very long range energy sources and policies. The three strategies are complementary in time scale, state of preparation, and parties at interest. The time scales for the selected strategies are: national energy conservation (near term to 1985), electrification (mid-term, 1985-2000), and diversification (2000 and beyond). These strategies are sets of related decisions.

The assessment procedure, as indicated above, included input/output analysis to determine the flows between sectors, and net energetics as part of a performance criterion for the conservation actions. The major feature of the assessment methodology was the identification of targets of opportunity for large net energy savings and for the application of advanced technology.

The potentials and impacts of citizens' actions were also discussed. The emphasis was on areas of large potential savings, the need for impact assessments, and the potential resistance of a reasonably affluent society.

### 13.1 UNRESOLVED ISSUES

An energy conservation program is a collection of chosen alternatives. Choices must be made in the selection of conservation actions, in assigning priorities to actions, in deciding on means of implementing actions, and on ways of enforcing the program. A complete assessment of a conservation program would require an analysis of the "ramifications" attendant with each choice. Because of time constraints, ECASTAR's assessment procedure focused on the evaluation of alternative (sets of) conservation actions. The primary emphasis in the evaluation process was identifying and, where possible, measuring the impacts that conservation actions would have on energy consumption, employment, and production. Left as unresolved or unanswered were issues such as the desirability of governmental initiative versus the operation of a free market to implement conservation. To a large extent, these non-quantifiable issues were bypassed because their ultimate evaluation depends on subjective criteria. Choices made regarding these issues are choices which provide the philosophical underpinnings of a conservation program. As such, an evaluation of the costs and benefits of alternative criteria is a necessary phase of the assessment process. In the text that follows, some of the "unresolved" issues are highlighted. These issues are organized around the major choices which define the tradeoffs.

### 13.1.1 CONSUMPTIVE LIFESTYLES VERSUS CONSERVATION ETHIC

To a large extent, typical energy users are not aware that their homes, cars, businesses, and industries are wasting energy. This is partially true because energy has been too cheap. User costs often do not reflect the efficiency and availability relationships between energy forms. Too much promotion, designed to increase the use of energy, has resulted in an unparalleled consumptive lifestyle. Considering the fact that each and every American has the equivalent of 80 energy men or 13 energy horses working for him leads one to believe that instilling the conservation ethic in the American public will be a monumental task.

While escalating energy prices will undoubtedly force adjustments in patterns of consumption, the variety of adjustment depends not only on prices, but also on tastes, lifestyles, and personal valuations of activities. The choices resulting from relying on a freely operating market are considerably different than the choices available from a market which is controlled via governmental intervention. How should these choice sets be evaluated? Who gains--who loses? How should these decisions be made? How important is individual choice and initiative in maintaining our quality of life... our economic viability? What assumptions are implicit in the argument that conservation can only be achieved by legislating action rather than by relying on voluntary action (whether conditioned by market forces or by a conservation ethic)?

It has been argued that we need conservation now. Conserving now involves choosing to consume less now so that there will be something (perhaps more) to consume later. Who makes this choice? What are the tradeoffs implied by the choice? At what point do markets (energy prices, e.g.) reflect the immediacy of the tradeoff?

### 13.1.2 ENVIRONMENTAL STANDARDS VERSUS ENERGY CONSERVATION

Some of the conflicts between energy conservation and environmental standards are obvious. For example, there are some aspects of environmental protection standards which would be at odds with both the spirit and mandate of parts of an energy conservation program. The debate surrounding the production of shale oil is indicative of this dilemma. Desulfurization of oil and coal requires additional energy in processing and refining. Other conflicts are less obvious. For example, forcing substitution for oil and gas results in increased consumption of coal or uranium with attendant environmental problems. As energy supplies become acutely scarce, should environmental standards regarding the use of high sulfur oil and of coal be relaxed? What are the choices and tradeoffs that society must make between these programs? What are the criteria that one would need to help evaluate the efficacy of these alternative actions? Again, who benefits--who loses? How should such decisions be made?

One of the major conflicts between environmental regulations and energy conservation is in the area of capital requirements: Meeting current environmental standards will require massive capital requirements; these will compete for the capital available for implementing conservation actions. Will there be sufficient capital available?

### 13.1.3 CAPITAL AVAILABILITY

In prescribing conservation actions, tradeoffs occur when finite resources can be used in competing ways. An obvious example is in finding the capital for implementing conservation. In terms of priority, how should capital be allocated--to energy conservation projects, to enhance environmental quality, to finance the expansion or replacement of productive capacity, or to further community development and promote urban renewal? How are priorities determined? How should they be determined? What are the costs and benefits which accompany any allocation scheme? Can priorities be determined by market criteria? What are the sources of capital and how can they be enlarged? What are the tradeoffs implicit in directing funds away from consumption activities and towards investment projects? What if the redirection is away from consumption and toward social investment? Should the government itself finance conservation? How are these decisions made?

### 13.1.4 CENTRALIZATION VERSUS DECENTRALIZATION

This controversy makes itself known in two related ways. The first represents the choice between market competition and government control. As Americans have seen, the presence of monopolistic elements in industry and the failure of the price system to take into account externalities and the approach to the end of resource supplies has led to increased government intervention. The debate is lively in Congress as to whether or not the "free" market should be allowed to determine its own energy course.

With FEA and ERDA, the government has obviously not decided to remove itself from the energy picture. Given this, the second problem arises as to whether to gear energy research and development toward one principal source or to all possible sources. To some degree, electrification and diversification present actions on opposite sides of the debate. Each strategy has important implications on the political and socio-economic structure of the U. S. In "crisis" periods, we have already seen a threat to the cohesiveness of the U. S. itself as fuel-rich areas were beginning to resent the dependence of fuel-poor areas upon them.

### 13.1.5 FUEL RICH REGIONS VERSUS FUEL POOR REGIONS

The recent enactment of a Louisiana law giving the state the option of retaining 20% of their gas production for sale within the state rather than shipping the gas out of the state (with severance tax) points out a developing conflict between the energy producing states and the energy importing states. The resolution of this conflict requires careful assessment and considerable mediation.

#### 13.1.6 SUPPLY VERSUS END USE CONSERVATION

Energy conservation to most people means increasing efficiency or curtailing use. Increasing efficiency and good housekeeping measures result in a reduction in consumption with few lifestyle changes. Therefore, these conservation actions have considerable support. On the other hand, reducing consumption in the final demand sector may, even though it does not have widespread public support, have potentially greater savings. The impacts and potentials of such actions must be assessed.

#### 13.1.7 LIFE CYCLE COSTING VERSUS INITIAL COST

The American consumer, in general, is concerned primarily with the initial cost of an item. In the past, he has been largely unconcerned with the operating cost or the life time of the appliance. Moreover, the consumer is not presently in a position to be able to determine the operating cost of most appliances. In the future, the consumer must be made aware of life cycle cost and the benefits derived from paying the higher front end cost.

#### 13.1.8 MANDATORY SAVINGS VERSUS VOLUNTARY SAVINGS

Many people feel that the potential for reducing energy consumption is great but that voluntary actions may not produce these savings. This argument contends that savings will be realized only if product efficiency is increased or if actions are mandated. A word of caution seems prudent at this point. Before a conservation action is mandated or legislated, a thorough assessment must be performed. The ECASTAR group feels that the systems approach-coupled with technology assessment is a viable tool for assessing these actions.

#### 13.1.9 LABOR INTENSIVE VERSUS CAPITAL INTENSIVE

An area which has received considerable attention involves the substitution between labor and capital. Is this substitution desirable? Is this substitution possible? What are the highest potential areas for trading off between capital intensive versus labor intensive operations? Should such a tradeoff be mandated or left to be determined by market forces? What are the ramifications of such tradeoffs on lifestyles, per capita food consumption, and growth?



### 13.1.10 GOVERNMENTAL CONTROL VERSUS FREE MARKET

The market system as it exists in the U. S. cannot be characterized as a purely competitive (or free) market. The energy market is no exception. For example, a free market would not include features such as the following: oil oligopoly, regulated utilities (both gas and electric), price fixing by means of public service commission rate structures, and administered prices (common in the oil industry).

One of the oldest forms of government intervention in the market is import duty. Another is import control (e.g. oil quotas). These controls have been used in the past to protect U. S. oil producers from foreign competition. They may be necessary in the future to protect domestic oil and/or domestic synthetic fuel industries from being undercut by low-priced foreign oil in the event the "knee-deeper" theory (that high prices will cause increased world-wide exploration and discovery, and the world will be "knee-deep" in oil) is correct. Import controls, however, can result in retaliatory measures by other countries. Therefore, such controls should be used with caution.

Some people feel that many of the energy problems faced by the U. S. today are the direct result of controls and regulations on oil and natural gas, not to mention restrictions affecting the various industries comprising the American transportation sector and current rate regulations governing utilities. These advocates of the free market argue that better planning and adaptation to dynamic economic circumstances can be accomplished, not by extending government regulations and controls on individuals and businesses, but rather by removing these restrictions and allowing these entities fuller freedom of action to meet future challenges. [Littmann-75]

Consider the problem posed by mandating energy efficiency standards. The case for compulsory standards on producers rests on the hypothesis that consumers, functioning in an unconstrained market, would select energy inefficient commodities over a more efficient but higher priced alternative. The standards are intended, of course, to restrict and limit the production and sale of items ranging from air conditioners to large (gas guzzling) automobiles. In fact, standards would also be used to force first costs to reflect the energy costs inherent in any commodity. The possibility that some consumers, even if the true life cycle costs were known and fully understood, would still choose to buy energy inefficient commodities is not admitted by the mandated hypothesis. Conservation can be achieved by driving a large automobile less frequently. By mandating uniform responses, the range of consumer response is constrained. To what extent should individual choice be discarded in deference to a preceived (and prescribed) common goal? Have we precluded against the possibility that a conservation ethic, in conjunction with an individual's personal valuation of a commodity, will be as effective as mandated action?

On the other hand, a careful examination of the energy situation reveals that the government may be able to influence the energy market without exercising unacceptable dictatorial control. Some of the options are already being exercised by government. Table 13.1.10-1 lists a variety of these options and some of the areas impacted by these actions.

TABLE 13.1.10-1. FEDERAL GOVERNMENT POLICY OPTIONS THAT IMPACT ENERGY PRODUCTION AND CONSUMPTION

Effect on:	Production					Consumption			
	Oil and Gas	Coal	Nuclear	Imports	Other(a)	Residential	Commercial	Transportation	Industrial
Policy Area									
Taxation	X	X	X	X	X	X	X	X	X
Price Controls	X	X	X	X	X	X	X	X	X
Import Controls	X			X				X	
Energy Performance Standards						X	X	X	X
Environmental Regulation	X	X	X	X	X	X	X	X	X
Land Use Regulation	X	X	X			X	X		X
Research and Development Support	X	X	X	X	X	X	X	X	X
Government Stockpiling	X	X	X	X					
Government Subsidy	X	X	X		X	X	X	X	X
Leasing Federal Resource Land	X	X	X		X	X	X		X
Building Codes						X	X		X
Allocation of Scarce Fuels	X					X	X	X	X
Mandatory Restriction of Energy Use						X	X	X	X
Control of Utilities						X	X		X

X = direct, definable effect

a) Geothermal, Oil Shale, and Solar

## 13.2 RECOMMENDATIONS

While it is left to policymakers themselves to examine the specific actions and assessments discussed in ECASTAR in terms of their own day-to-day decisions, some broad recommendations are given in the sections below.

### 13.2.1 UTILIZE SYSTEMS APPROACH

After using the systems approach to study energy conservation, the group felt that it was a valuable tool with which to assess conservation actions "in toto". In using this approach, any conservation actions or group of actions must be characterized in terms of a clearly defined group of constraints and criteria that are established before beginning to construct a conservation policy or strategy. These constraints and criteria may need modification during the iterative process.

Feasible actions can be identified by applying the constraints and criteria to all the actions. These actions must be analyzed further to determine the impacts on other sectors, society, economy, environment, etc. This could lead to a listing of advisable actions (those having impacts which are least objectionable).

Two of the methods of analysis displayed in the study (undoubtedly there are more) were net energetics and input-output analysis. These techniques provided a method for a more in-depth examination of contemplated actions. This second look, which is not often taken, may be of utmost importance.

### 13.2.2 PROVIDE ACTION/IMPACT ASSESSMENT

Many conservation actions have been proposed -- few have been subjected to a thorough analysis. The group feels that the systems approach, coupled with technology assessment, can be used to provide the in-depth analysis needed to assess a potential conservation actions. For example, if a consumer is going to be asked to make a significant lifestyle change, he naturally wants to know what the results of these changes will be. He might also be interested in being informed as to the alternatives to this particular course of action. Citizens may be much more cooperative in saving if they understand that continuing consumption may result in unnecessary adverse impacts. In other words, the advantages and disadvantages of each action can be displayed when the action is proposed.

### 13.2.3 ESTABLISH REGIONAL ENERGY CENTERS

The ECASTAR group recommends that regional energy centers be established throughout the nation. These centers would be interdisciplinary in that they will possess expertise in the many areas that bear on the energy situation, e.g. technical, legal, environmental among others. The center would be a disseminator of energy information to interested parties and serve as a focal point for organization of citizen participation in

energy matters. In addition, such a center would be able to collect, analyze and verify regional level information on the impacts of energy policies. The advantages of a regional level organization are the following:

Regional energy centers could allow more citizen participation in the decision-making process. Increasing citizen involvement may result in greater response to energy conservation challenges.

Regional centers should be able to present a more personal view of the energy problem to the residents of that region. Much of the potential for conservation resides with the individual consumer. For this reason, a large, centrally located federal program may not be as effective as regional centers from which viable information could be more easily dispersed. The ultimate success of any energy conservation program lies in consumer acceptance of that program.

The problems facing each region may be similar, but they are not the same. Problems could be identified by region. Some data are already available by regions, and collecting additional data should be easier on a regional basis. Industries, with their specific problems, could be identified and dealt with initially on a regional basis, e.g. the Prengle study on Texas industry [PRE-74].

The I/O model could be disaggregated by regions or states. Then, these regions could be connected so that differential impacts over time might be identified. Existing econometric models of regions and states would be easier to link to such a regional model.

The regional energy center would function and interact with various groups as shown in Figure 13.2.3-1. Information and expertise on energy matters would be transmitted to such parties as citizens' organizations and governmental units. These groups, partly through their use of this information, would develop local and regional energy policies. These policies would make major contributions toward developing national energy policies. Also, feedback to the energy centers as a result of the interactions would be analyzed by the center for impacts, policy assessments and other vital information. This data would be forwarded to other individuals and groups for additional analysis and national energy policy formulation.

#### 13.2.4 DEVELOP CONSTRAINTS AND CRITERIA FOR EVALUATING ENERGY ALTERNATIVES

A basic reason for failure to develop a national energy policy has been the inability to arrive at a consistent set of constraints and criteria for evaluating energy alternatives. A program of national energy independence may ultimately result in increased inflation, capital shortages, unemployment and other undesirable social impacts. What is the country willing to pay for what degree of energy independence? These ideas have not been adequately presented to the formers of public opinion with the consequence that no national consensus has yet been achieved.

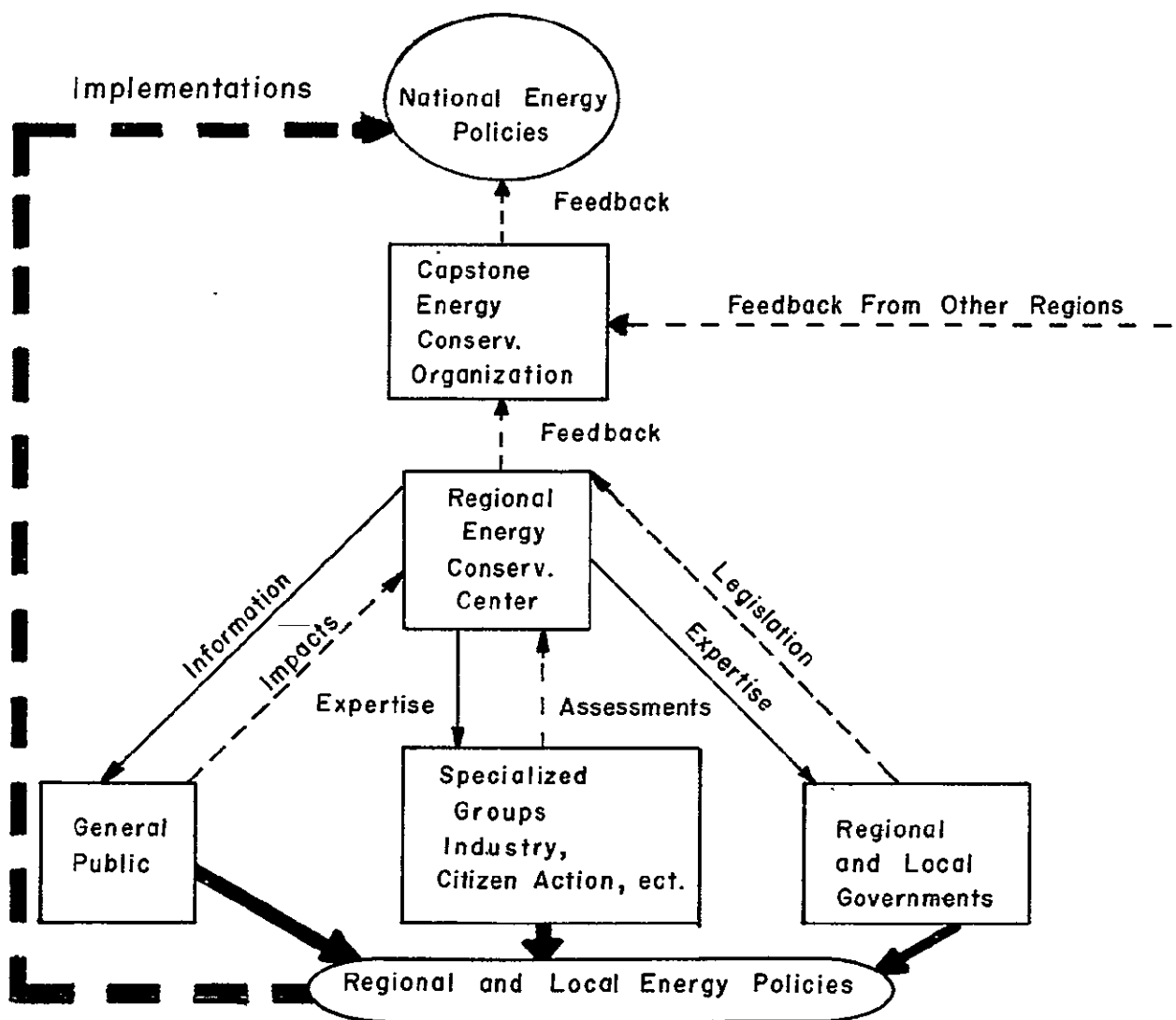


FIGURE 13.2.3-1. INTERACTIONS OF REGIONAL ENERGY CENTERS

While several organizations have served to propose solutions to the problems, nowhere have these proposals been evaluated on a systematic comparative basis. The failure to carefully analyze the fundamental constraints and criteria has heretofore precluded such evaluation and has forestalled efforts to arrive at a consensus in developing an overall policy. The recommendation is made that a broadly based task group drawn from technical, legal, economic and public sectors be formulated to aid in developing a generally acceptable set of overall constraints and criteria.

### 13.2.5 IMPROVE TECHNOLOGY ARTICULATION WITH GOVERNMENT

The group urges that a climate be created which will enhance the articulation between persons and institutions directly responsible for technical inventions and those responsible for creating the laws of the society.

Issues dealing with energy supply and conservation are among the more contemporary examples of the interrelationships between technology, science, and the political process. Unfortunately, it appears as if the communication links between the "technical inventors" (engineers and scientists) and the "social inventors" (legislators) are but weak and tenuous and in need of strengthening.

Engineering has been defined as the application of the fruits of science to the "benefit" of mankind. The word "benefit" is the challenging one. That which accrues as a benefit to one individual may very well be another individual's cost. As technology assumes a more pervasive role in our society, as our life styles increasingly become linked with our choices of technology, perhaps a new look needs to be taken at the ways in which our society allocates resources. It is necessary to determine who bears the costs and who reaps the benefits arising out of decisions involving technology. As local, state, and federal governments increasingly grapple with technological issues, it becomes apparent that the big questions the political system determines are resource allocation and the distribution of costs and benefits within a society.

Since the links between "technical inventors" and "social inventors" are perceived to be less than ideal, steps should be taken by both the technical community and the legislative community to create a climate which can strengthen these links. Specific actions in this direction might be to:

- Establish systems analysis and technology assessment capability within legislative bodies at all levels of government. The composition of such activities and modes of integration and operation will be somewhat unique for each level. Perhaps at the local and state levels a substantial degree of citizen participation is needed so that feedback to the community can be enhanced.

Create engineering and science internship positions at all levels of government so that technical students might have the experience now available to political science, economics, and law students. By this means, the systems analysis and technology assessment point of view might be used on some of the technology-legal issues being addressed by law makers.

Establish reward structures within academic institutions to encourage these persons to make contributions at the technical-legal interface.

Assumptions in the above include the following:

Engineering, science and technology play an increasingly complex interactive role in our society;

Large issues involving technology are resolved by our political system;

Our political system works best when it is used by our citizens; and

Engineering, science and technology involvement in this political process is not as strong as it should be in view of items one and two above.

#### 13.2.6 DESIGN TOTAL ENERGY SYSTEMS

Our society has reached a point in time when we should use the systems approach to explore alternative energy systems for the future. Present R & D activities by a new institution, ERDA, represent a step in that direction, as discussed in Chapter 11. But perhaps an even broader perspective is needed.

Why now? It has been said that western technological society in many ways is at a watershed point in history. A major perturbation to our system, such as the one it received from the recent oil shortage problem, can be a major stimulus which is capable of eliciting a host of creative, innovative responses in technical and socio-institutional ways. To an engineer, for example, the requirement that he create his design within a new framework of energy constraints can lead to many new and ingenious ways to meet the problem. In a broader sense, an institutional response to the "energy crisis" is already evident in the creation of several new institutions for coping with energy problems. ERDA is a prime example of this kind of institutional response.

There are many other trends apparent in our society at this time which suggest that now is the time to look broadly at alternative energy systems. One area which perhaps needs to be given more attention, from a systems analysis and technology assessment point of view, is the design of total energy systems which are decentralized and which return autonomy in energy source to individuals or smaller institutional entities such as

neighborhoods, cities or regions. Illustrative of such systems are the Modular Integrated Utility Systems (MIUS) which are presently being explored by Housing and Urban Development (HUD) and NASA. Developments in solar, wind, trash burning and other energy systems coupled with the climate of "creative shock", discussed earlier, might produce (with additional R & D) very fruitful, economically feasible, decentralized total energy systems for our future.

Total energy systems of a decentralized nature imply major shifts in contemporary institutional arrangements and lifestyles such that it is imperative that a systems approach and technology assessment be used in exploring these possibilities.

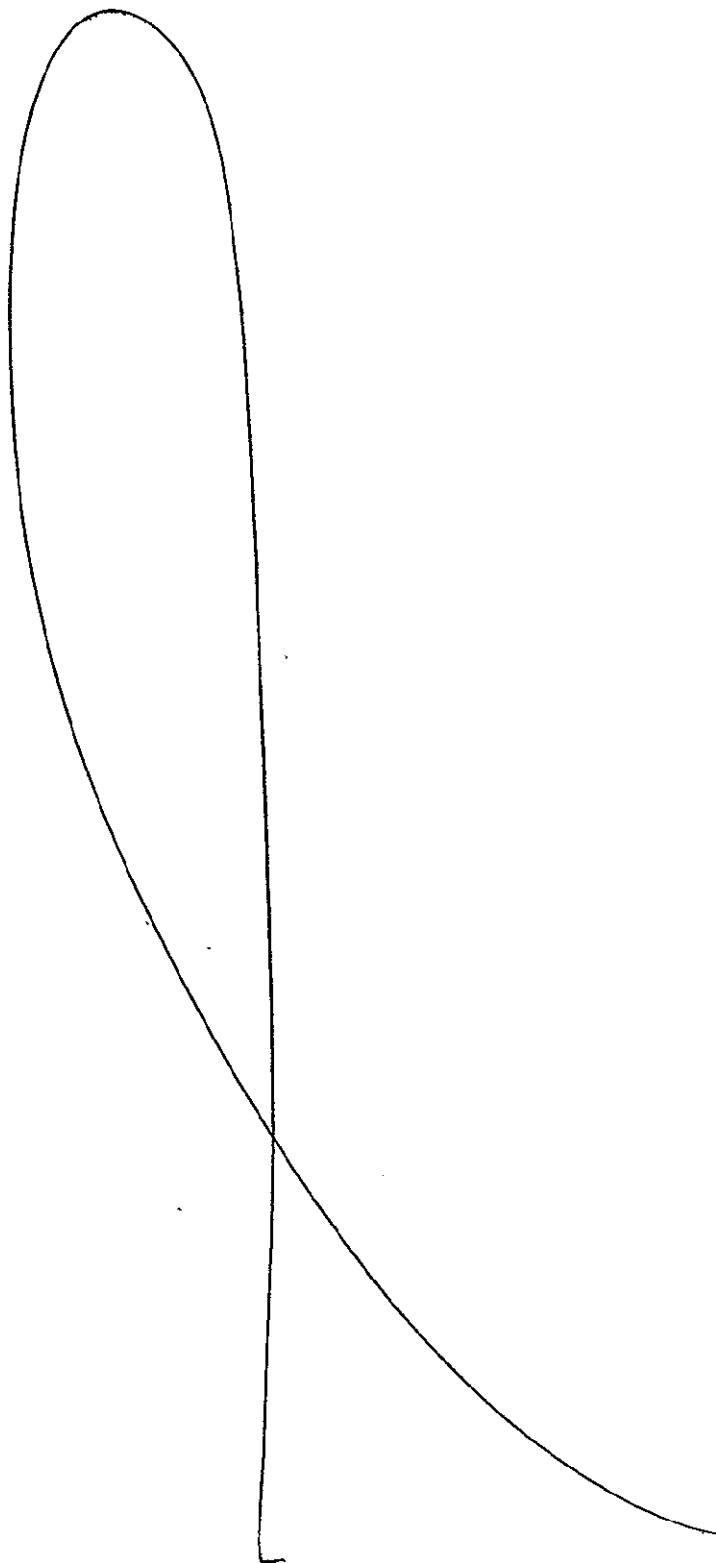
### 13.2.7 UTILIZE EXISTING SYSTEMS APPROACH EXPERTISE

As the results of the research and development and data collection programs accumulate, the need for a way to integrate all this information becomes evident. Large systems planning is required. One way to organize this mass of data is to formulate a methodology for integrating the diversity of information from ERDA, FEA, the proposed regional energy centers, etc. This methodology could provide an integrated energy system that is badly needed by this country. It would help in establishing priorities for research funding, in formulating national energy policy, and in providing a constant interactive process for refining the data. The cooperation of organizations and institutions with expertise in the systems approach and technology assessment methodology would be needed to initiate such a program for long range planning for the nation.

### 13.3 EPILOGUE

These recommendations will not, of course, end the energy policy impasse. They are meant to give direction and organization to the task of gaining information and insight on an energy future with conservation as a significant variable. It is indeed time for all specialists to become interacting members of a "united whole" so that energy options will be put in correct perspective.





## APPENDIX A. ABBREVIATIONS

AEC	- Atomic Energy Commission	GAL	- Gallon
BBL	- Barrel, Petroleum Measure, 42 Gallons	GE	- General Electric Corporation
BEA	- Bureau of Economic Analysis	GWe	- Gigawatt Electrical
BLS	- Bureau of Labor Statistics	HP	- Horsepower
BTU	- British Thermal Unit	HTGR	- High Temperature Gas cooled Reactor
BWR	- Boiling Water Reactor	ICC	- Interstate Commerce Commission
CAB	- Civil Aeronautics Board	IES	- Illuminating Engineering Society
CAC	- Center for Advanced Computations	I/O	- Input-Output
CD	- Calendar Day	KWe	- Kilowatt Electrical
CDAY	- Calendar Day	KWh	- Kilowatt-Hour
COP	- Coefficient of Performance	LCC	- Life-Cycle Cost
DA	- Day	LMFBR	- Liquid Metal Fast Breeder Reactor
DOC	- Department of Commerce	LNG	- Liquid Natural Gas
DOI	- Department of Interior	LWR	- Light Water Reactor
DOT	- Department of Transportation	Manuf	- Manufacture
EBOPD	- Equivalent Barrels Oil Per Day	MBT	- Minimum Spark Timing for Best Torque
EC	- Energy Cost	MBTU'S	- One Thousand BTU's
EHV	- Extra High Voltage	MMBTU'S	- One Million BTU's
EI	- Energy Intensiveness	MCF or MMCF	- Million Cubic Feet
EEA	- Energy and Environment Analysis Incorporation	MCFDA	- Million Cubic Feet per Day
EPA	- Environmental Protection Agency	MPG	- Miles per Gallon
EPRI	- Electric Power Research Institute	MPH	- Miles per Hour
ERDA	- Energy Research and Development Administration	MSFC	- Marshall Space Flight Center
ESI	- Equivalent Sphere of Illumination	MVA	- Mega Volt-Amperes
F	- Fahrenheit	MWe	- Megawatt Electric
FE	- Fuel Economy	NASA	- National Aeronautics and Space Administration
FEA	- Federal Energy Administration	NBS	- National Bureau of Standards
FPC	- Federal Power Commission	NCSL	- National Conference of State Legislatures
FT	- Feet		

NG	- Natural Gas
NGL	- Natural Gas Liquids
NPC	- National Petroleum Council
NRC	- National Regulatory Commission
NSF	- National Science Foundation
OCS	- Outer Continental Shelf
OPEC	- Organization of Petroleum Exporting Countries
PM	- Passenger Miles
PWR	- Pressurized Water Reactor
QUAD	- Quadrillion BTU ( $\text{BTU} \times 10^{15}$ )
R&D	- Research and Development
RD&D	- Research Development and Demonstration
S	- Sulfur
SCB	- Survey of Current Business
SCF	- Standard Cubic Feet of Gas
SIC	- Standard Industrial Classification Code
SNG	- Substitute Natural Gas
SPG	- Synthetic-Pipeline Gas
SRI	- Stanford Research Institute
TCF	- Trillion Cubic Feet
Thous	- Thousands
UHV	- Ultra High Voltage
UMTA	- Urban Mass Transportation Administration
USGS	- United States Geological Survey
VM	- Vehicle Miles
YD	- Yards
YR	- Years

B-1

## APPENDIX B. UNITS AND CONVERSION FACTORS

Despite attempts to institute a universal set of physical units, there are units of measure that are peculiar to various segments of industry. Thus, in order to compile data for all of industry, unit equivalences must be known.

Table B-1 lists several of the energy equivalents used in this report. Table B-2 defines the prefixes and their symbols in use today. Several commonly needed conversion factors are presented in Table B-3.

### B. 1 ENERGY UNITS

The British Thermal Unit (BTU) is the basic unit of energy in many measurements. A BTU is defined as the amount of heat energy required to increase the temperature of one pound of water by one degree Fahrenheit. The quad is one quadrillion ( $10^{15}$ ) BTU's. The quad should not be confused with the Q which has been used in the past and was defined as  $10^{18}$  BTU's.

The watt-hour is a unit often used to express quantities of electrical energy. The watt-hour is equivalent to 3.41 BTU's.

The barrel (bbl.), used as an energy unit, refers to the standard barrel (42 gallons) of crude oil and is defined as having an energy content of 5,800,000 BTU. Thus, the energy content of any fuel can be expressed in barrels of crude oil equivalent (BCOE). For instance, heavy distillate has a higher energy content than crude oil (6,960,000 BTU/bbl.) so that its energy rating is 1.2 BCOE/bbl. The equivalent energy value of crude oil plus natural gas liquids, NGL, ( $5.5 \times 10^6$  BTU/bbl.) is .95 BCOE/bbl. This combination is peculiar to oil and gas production statistics.

### B.2 POWER PLANT RATINGS

Care must be exercised when plant capacities are considered. Confusion often exists as to whether the thermal energy input or the electrical energy output is being discussed. The thermal input and electrical output are related through the efficiency of the particular power plant. The rated output normally refers to the plant's maximum capacity to produce power. Thus, a nuclear power plant having a rated electrical output of 1 GW would be "burning" 3 GW in reactor fuel when at maximum capacity.

However, power plants do not run at maximum capacity all of the time since the load to be met will vary hourly. Also, the maintenance down-time of the plant must be considered. Overall, the load factor and plant factor, with the plant's efficiency, determine the amount of energy consumed by a plant. The equation below shows the relation between rated capacity and energy used.

$$GWe = \frac{Q \cdot N}{L} \quad (B.2-1)$$

Where,

GWe = rated electrical capacity

Q = energy in fuel burned

N = thermal efficiency

L = load factor

TABLE B-1. ENERGY EQUIVALENTS

1 barrel (42 gallons) of crude oil	= $5.8 \times 10^6$ BTU
1 barrel of crude oil + NGL	= $5.5 \times 10^6$ BTU
1 cubic foot of natural gas	= 1035 BTU
1 gallon of gasoline	= 125,000 BTU
1 BTU	= 1055 joules
1 Kilowatt	= $10^3$ watts electrical
1 Megawatt	= $10^6$ watts electrical
1 Gigawatt	= $10^9$ watts electrical
1 Kilowatt hour	= 3412 BTU
1 Quad	= $10^{15}$ BTU
1 Quad	= $1.724 \times 10^8$ barrels of crude oil
1 Quad	= $40 \times 10^6$ short tons of coal
1 Quad	= $9.662 \times 10^{11}$ ft. <sup>3</sup> of natural gas
1 Quad	= $70 \times 10^6$ short tons of lignite
1 Quad per year	= 0.472 million barrels of crude oil per day

TABLE B-2. PREFIXES

Multiplier	Prefix	Symbol
$10^{12}$	tera	T
$10^9$	giga	G
$10^6$	mega	M
$10^3$	kilo	k
$10^2$	hecto	h
10	deka	da
$10^{-1}$	deci	d
$10^{-2}$	centi	c
$10^{-3}$	milli	m
$10^{-6}$	micro	$\mu$
$10^{-9}$	nano	n
$10^{-12}$	pico	p
$10^{-15}$	femto	f
$10^{-18}$	atto	a

TABLE B-3. CONVERSION FACTORS

<u>To Convert From</u>	<u>To</u>	<u>Multiply By</u>
angstrom (A)	meter (m)	$10^{-10}$
British thermal unit (BTU)	joule (J)	1055
calorie (c)	joule (J)	4.18
erg	joule (J)	$10^{-7}$
horsepower ( $h_p$ )	watt (W)	746
kip	newton (N)	4448
langley	joule/meter <sup>2</sup> (J/m <sup>2</sup> )	41840
phot	lumen/meter <sup>2</sup> (lm/m <sup>2</sup> )	10000
kilowatt hour (kWh)	joule (J)	$3.6 \times 10^6$
BTU/second	watt (W)	1055
cubic foot	gallons	7.48
acre	square feet (ft <sup>2</sup> )	43,560
acre-foot	gallons	325,851
<u>Temperature</u>		
Celsius (C)	kelvin (K)	$t_K = t_C + 273.15$
Fahrenheit (F)	kelvin (K)	$t_K = \frac{5}{9} (t_F + 459.67)$
Fahrenheit (F)	Celsius (C)	$t_C = \frac{5}{9} (t_F - 32)$
Rankine (R)	kelvin (K)	$t_K = \frac{5}{9} t_R$

## APPENDIX C. ALTERNATE ENERGY PERFORMANCE CRITERIA

In evaluating actions that may be considered conservation, there is a need to establish a criterion in terms of energy use itself. This appendix begins with a discussion of efficiency in general. It goes on to discuss thermodynamic and economic efficiencies as they relate to energy choices. These are brought together as they relate to the criterion most used in the real world, the criteria that should be used and the implications of any imposed criteria on energy systems. Some broad and specific examples are evaluated in terms of these criteria, especially "net energetics".

### C.1 EFFICIENCY CRITERIA

Efficiency is defined as the ability to produce a desired effect with a minimum of effort, expense or waste. A coefficient is generally associated with it, but the word is often used without explicit reference to the specific units of measurement, the specific desired effect and the system for achieving such an effect. The intent of this section on energy performance criteria is to provide a partition of energy decisions made under different concepts of efficiency.

"Effort" in the above definition shall be considered as the amounts of energy (First Law of thermodynamics) or available work (Second Law) that are associated with achieving the desired effect. This is discussed in Section C.1.1. "Expense" in Section C.1.2 implies the dollar costs of an action expressed in a first-cost or a life-cycle cost sense. "Wastes" are characterized in Section C.1.3. These concepts are brought together in Section C.2 in terms of their implications for energy conservation. In Section C.3, the big issues, which are the main focus of this report are broadly evaluated in terms of our energy performance criteria. A somewhat analogous endeavor is undertaken in Section C.4 for comparisons between alternate methods for steam generation for a 100 MW electrical generating plant. The alternates are solar, nuclear, coal and oil, compared on bases of first cost and life cycle cost; a net energetics analysis is also given for the solar.



### C.1.1 EFFORT

The energy measure most often used when evaluating the performance or setting goals for technological improvement of engines, appliances, industrial processes etc. is energy efficiency which arises from the First Law of thermodynamics. The First Law may be stated as: Energy can be neither created nor destroyed, but only converted from one form to another. First Law energy efficiency is a comparison of the useful energy output of a process or system to the energy input necessary to obtain that desired output. Thus an increase in energy efficiency can be thought of as a decrease in the amount of energy (effort) necessary to produce a desired output.

When making comparisons between alternate ways of performing an activity or setting a goal for that activity in terms of energy efficiency, the definition of the specific situation must always be carefully stated. That is, the efficiency that is being referred to must be defined relative to a system and a process. There are many energy efficiencies that can be defined for a given system. The choice of which to use is often the deciding factor in whether the system performance is good or bad. For example, when referring to the efficiency of a power plant, a qualifying statement must be made as to whether the energy input is taken to be the raw fuel energy in or the heat input to the working fluid at the boiler. Likewise, the point of measurement and form of the energy output must be stated. Is it the electricity at the bus bars, electricity delivered to end use or total energy out of the system consisting of electricity plus the heat energy out in the cooling water. This concept must also be kept in mind when specifying standards of performance or desired increases in performance, and when comparing two energy using systems or devices. An example is the setting of a goal of 20% increase in efficiency for a specific type of energy-using consumer product. The definition of efficiency must be cast in terms of specific statements as to what the input and output energies are, and how they are to be measured.

The First Law of thermodynamics states that all forms of energy are equivalent in that, when one form of energy disappears, an equal quantity in another form appears. The First Law makes no attempt to designate whether or not a system or process is ideal or to specify the direction the process must take. For all systems the First Law is a bookkeeping device to ensure that energy is neither created nor destroyed but merely changed in form. The second law of thermodynamics recognizes that all forms of energy are not equal in their ability to do work -- some forms of energy are more valuable than others. All real processes convert energy from the more useful to the less useful forms, i.e., energy is degraded. For example, high-quality energy (fossil fuels, nuclear energy, hydropower) is converted to other forms of high quality energy (electricity, work, high temperature heat) plus some low quality energy (low temperature heat). As an example of the difference in grade of energy, consider the energy contained in the cooling water from a power plant. Although this water contains a great deal of energy, its quality is low. That is, because of its very low

temperature, very little useful work (high grade energy) can be obtained from it. The First Law of thermodynamics cannot reflect the degradation of energy from high grade to low grade during an energy conversion process since its satisfaction merely requires energy's being conserved. A measure of the performance of a system which does reflect the degradation of energy is the Second Law efficiency or effectiveness. The effectiveness is defined in terms of available energy which is actually consumed in a process unlike energy which is conserved. "Available energy is the maximum portion of energy that could be transformed into useful work by processes which reduce the system to a state in equilibrium with the earth and its atmosphere" [Obert-63]. The effectiveness is defined as:

$$\epsilon = \frac{\text{increase in available energy of desired output}}{\text{decrease in available energy required to obtain output}}$$

That is, it is the ratio of the least available energy that could perform the task to the available energy actually consumed in doing the task with a particular system or device. The utility of the Second Law efficiency is that it emphasizes processes where there is a mismatch between the grade of the input energy and the grade of the desired energy output. For example, although the First Law efficiency of a gas furnace is 70%, its effectiveness is only about 13%. Since the desired output from this system is low grade energy (low temperature heat), the low value of the effectiveness is an indication that high quality energy has been used to obtain a low quality result or that low quality energy input could have been used to obtain the same desired result. A good example of a process that would have a high effectiveness and use low grade energy (e.g., from the cooling water mentioned above) would be to use waste heat from a power plant or industrial process for space heating. A more subtle example would be an indication that more emphasis should be placed on improving combustor performance in a power plant than on improving the condenser performance. This is true because more available energy is lost in the combustor than in the condenser although the opposite is true for energy losses.

The effectiveness is an indicator of how well a specific device executes specific task relative to how efficiently that task could have been performed by an ideal (best possible) device. It is also a measure of how much improvement is possible. Maximizing the effectiveness will minimize energy consumption for a given task. The distinction between First and Second Law efficiencies may be extremely important in that it could indicate where funds should be allocated for research and development aimed at increasing energy performance of systems and devices.

The concept of energy efficiency can be extended to include all the energy inputs necessary to obtain a good or service, i.e., NET-ENERGETICS. Net-energetics is an energy accounting scheme whereby the total energy cost (energy inputs in BTU, kwh, etc.) of providing a good or service is considered. Only when we know the total energy cost of a good or service, can we determine the energy conserved by consuming one good or service instead of another, or by substituting a new technology for another. Energy inputs (or cost) to provide a good or service are classified as direct

or indirect. Direct energy is that consumed at the end-use point, such as oil used in a furnace, gasoline used in an automobile or electrical energy to produce a given product. Indirect energy is that which has gone into the various activities and raw materials which were necessary for the production of a good or service, such as energy which has gone into the production of the raw materials, energy expended to provide plant and equipment, etc. There are several levels at which net energetics can be applied, distinguished from each other by the degree to which indirect energy costs are charged to the good, service, or process. Figure C.1.1-1 illustrates various levels of net energetics. This concept is similar to economic analysis in that accounting techniques charging overhead to the production cost per unit of output and life cycle costing are used. These techniques have been extensively employed, but the energy costs have not been handled in this way. Energy costs are embodied to some degree in financial costs.

At its simplest level, a net energetics analysis considers the energy required to produce a given product. This energy is subtracted from the energy which will be saved if the product or process is substituted for another. For example, if insulation is installed in a house to decrease the energy consumption for space heating, the energy cost of producing that insulation would be subtracted from the gross energy savings to determine a net savings over the life of the insulation (assumed same as house). The next level would consider the conversion and distribution losses associated with the energy used in producing the insulation on until a portion of all energy inputs associated with the product are charged to it. In addition, the money saved by the home owner might be used to buy goods or services which have energy inputs associated with them which, in a complete analysis, should also be charged in part to the insulation (cf. Table C.1.1-1). One means of performing a net energetics analysis, especially when many levels are to be studied, is to use an input-output model of the economy. This technique can be employed to study the effect that a change in energy demand in one sector has on all other sectors' energy demands. It can also be used to determine all the energy inputs, both direct and indirect, that go into a unit of a good or service. This identifies areas with high energy use and high potential for energy conservation. An example of how this technique would be applied to computations of various levels of net-energetics is given below. The essential point is that net-energetics can look at the direct and indirect energy costs of any output of the system. Although the initial thermodynamic focus is on energy to get energy, the input-output analysis can be used to expand this to energy to get products and services.

The input-output total and direct requirement's matrices can be used to illustrate various levels of net energetic computations. For this discussion assume there are only 3 industries in the economy: mining, manufacturing, and energy. The total and direct requirements are given in Tables C.1.1-2 and C.1.1-3.

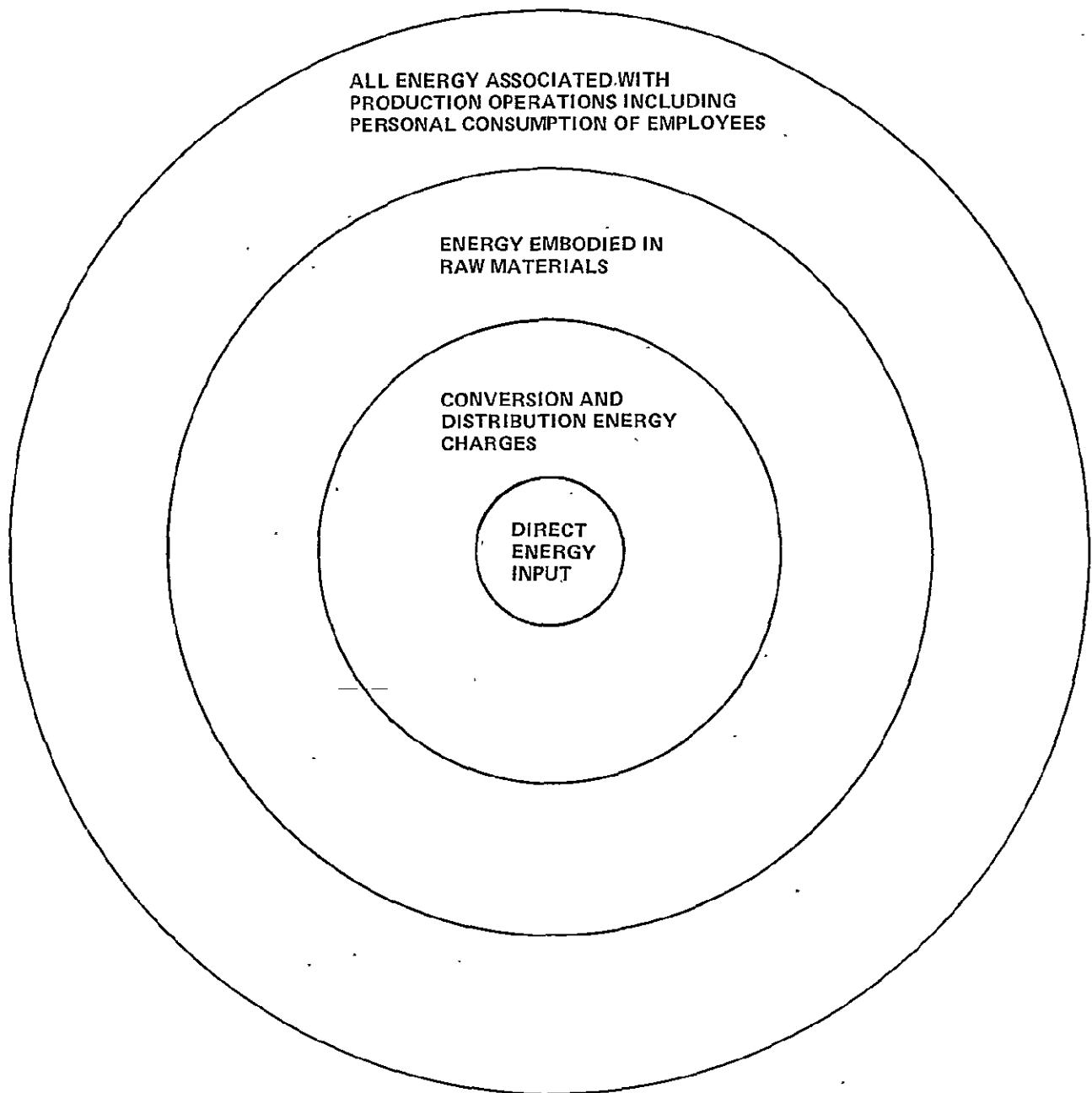


FIGURE C.1.1-1. LEVELS OF NET ENERGETICS

TABLE C.1.1-1. THE ENERGY AND LABOR INTENSITY OF 20 ACTIVITIES OF HIGHEST PERSONAL CONSUMPTION EXPENDITURES (PCE) [Hannon-75]

PCE sector description	Energy intensity (Btu per dollar)	Labor intensity (jobs per \$1000)	PCE sector description	Energy intensity (Btu per dollar)	Labor intensity (jobs per \$1000)
Electricity	502,500	0.0436	(Federal taxes)	(36,300)	(0.082)
Gasoline and oil	480,700	0.0729	Women's and children's clothing	38,100	0.1000
(Housing)	-(144,000)	(NA)	Restaurants	32,400	0.0875
(Auto ownership)	(111,500)	(.081)	Men's and boys' clothing	31,400	0.0984
Cleaning preparations	78,100	0.0733	Religious and welfare activity	27,800	0.0863
(Average PCE)	(70,000)	(0.080)	Private hospitals	26,100	0.1718
Kitchen and household appliances	58,700	0.0551	Automobile repair and maintenance	23,500	0.0483
New and used cars	55,600	0.0775	Financial interests except insurance	21,500	0.0784
Other durable house furniture	54,600	0.0894	Tobacco products	19,800	0.0585
(Private investment)	(45,600)	(0.066)	Telephone and telegraph	19,000	0.0585
Food purchases	41,100	0.0852	Rented home	18,300	0.0350
Furniture	36,700	0.0917	Physicians	10,700	0.0325
			Own home	8,300	0.0167

TABLE C.1.1-2. TOTAL REQUIREMENTS

Dollars of input to produce one dollar of final demand

	Energy	Mining	Manuf.
Energy	1.3	.2	.4
— Mining	.2	1.2	.1
Manuf.	.1	.1	1.3

TABLE C.1.1-3. DIRECT REQUIREMENTS

Dollars of input per dollar of total output

	Energy	Mining	Manuf.
Energy	.20	.11	.24
Mining	.13	.29	.18
Manuf.	.06	.06	.27

Further assume we know total BTU's purchased by mining and manufacturing, and total BTU's supplied by energy. The transacted BTU/\$ ratios are given in Table C.1.1-4.

One way of assigning an energy cost (E.C.) to a dollar of total output is to simply use the transacted BTU/\$ ratio. At this level energy cost/\$ is 5, 10, and 10 BTU's respectively.

#### Level 1

The total requirements matrix shows what the total input requirements are to produce \$1 of final demand. These inputs can be converted to BTU inputs and summed to get the E.C. in terms of transacted BTU's for each input. For example, under this scheme the E.C. for the energy industry would be:

$$[1.3 \times 5] + [.2 \times 10] + [.1 \times 10] = 9.5 \text{ BTU's/\$}$$

The numbers (and E.C. rankings) change because each input may have different level 1 E.C.'s (cf. Table C.1.1-5).

#### Level 2

If the numbers in Table C.1.1-5 represent more precise estimates of the energy cost to produce \$1 of final output, we can recompute the BTU total requirements. For example, the E.C. for the energy industry would now be:

$$[1.3 \times 9.5] + [.2 \times 13.0] + [.1 \times 16] = 16.55 \text{ BTU's}$$

Some care should be used in interpreting this number. 16.55 represents the E.C. based on directly transacted BTU's (5, 10, 10) and on the non-directly purchased energy imbedded in the inputs. (viz. 4.5, 3, 6, are determined by subtracting corresponding elements in Table C.1.1-4 from those in Table C.1.1-5).

### C.1.2 EXPENSE

Efficiency in a broad economic sense is achieved when society chooses an allocation of resources such that no one individual can be made better off (in terms of his own evaluation) without making at least one other individual worse off. An important aspect of this idealized criterion is that it is difficult to compare individual values to each other in any meaningful way. Hence, statements cannot in general be made regarding the al-

TABLE C.1.1-4. TRANSACTED BTU/\$

Energy purchased as such to produce one dollar of final demand.

Energy	1.5
Mining	2.10
Manuf.	3.10

TABLE C.1.1-5. LEVEL 1 E.C. BTU'S (\$ FINAL DEMAND)

		direct	+	indirect
Energy	9.5 =	5	+	4.5
Mining	13.0 =	10	+	3.0
Manuf.	16.0 =	10	+	6.0

TABLE C.1.1-6. LEVEL 2 REEVALUATED ENERGY COST

Energy	16.5
Mining	19.1
Manuf.	25.9

location of energy resources among individuals. It is then left to the marketplace to provide individual agents with prices upon which they make energy decisions. Since these prices fail to take into account external by-products caused by these decisions (e.g., pollution, urbanization, etc.) and the approach of scarce resources to their inevitable limits, market decisions based on them are thought unreliable in a social sense.

In the absence of some social welfare index, we must look at individual decisions in terms of the costs to the individual himself and simply postulate on the impacts of his actions. In making energy systems choices, the individual may consider only the initial costs (labor, machinery, materials, etc.) of implementing that system. Many decisions are made according to first-cost efficiency. This means that an individual will choose the system which minimizes the initial cost of implementation. There is no attention paid to the operation of the system through time.

A second expense criterion is called the system life-cycle cost method. It incorporates not only the initial cost of the energy system, but the discounted present value of the stream of expected energy costs in the future. If  $P$  is the present price,  $r$  the discount rate,  $n=1, \dots, N$  the number of periods of asset life and  $C_n$  the operating costs in period  $n$ , then the formula for life-cycle cost, LCC, is

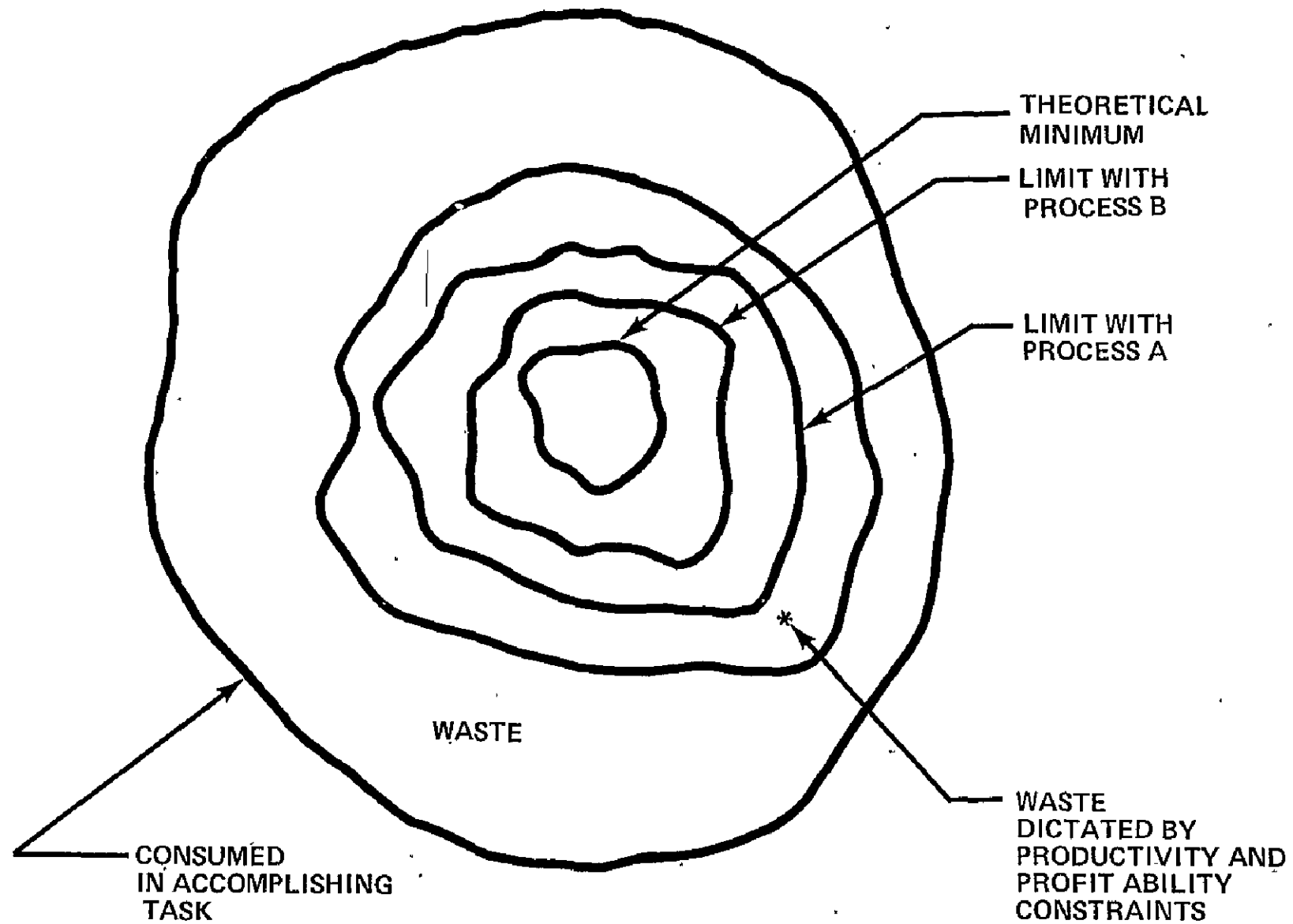
$$LCC = P + \sum_{n=1}^n \frac{C_n}{(1+r)^n} \quad (C.1.2-1)$$

Although it is in dollar terms, it accounts for energy utilized at prices that are expected to go up in the future by at least the rate of inflation. The individual's feeling about the future is incorporated in the subjective discount rate. It is felt, then, that LCC is a better criterion for energy decisions. Although major business concerns have used it for some time, the residential and small commercial decision-makers seem largely unaware of it. It is intermediate between first-cost and the net-energetics criteria proposed above.

### C.1.3 WASTE

Figure C.1.3-1 depicts the order of attack of an efficiency program on waste. The total consumption to accomplish the task has a peripheral amount which attention or technology could reduce or eliminate. Next there is an amount of consumption dictated by the practical consideration of producing goods and services at a profitable rate. There two elements of the waste stream could in principle be converted to useful products if a task could be developed to utilize the waste stream or if the process could be modified to render the stream useful. Waste control is therefore not just elimination. There is potential for turning waste to productive ends.





WASTE AND PERFORMANCE LIMITS PICTORIALIZED

FIGURE C.1.3-1.

A trade off exists at the next level, that of alternate processes. Careful consideration should be given to the character of the waste stream in seeking lower total consumption. It could well be that more benefits could follow from a process which consumes slightly more in accomplishing the task if the waste stream is tailored to some task. The opposite is even true in that old "wasteful" processes may be retained in order to preserve a secondary process dependent on the waste stream. This attitude of analyzing with the product and waste streams for increased potential utility will increase as we exhaust the easy waste reduction options and move on to major actions involving whole system substitutions instead of component or sub-system changes.

The third point to be gleaned from the diagram is that the best measure of achievements or potential is the state of the art limits, not the theoretical limits. As was pointed out in Chapter 3, most tasks do not have a theoretical limit such as the Carnot efficiency because they require evaluation of intangibles. The suggested rule is to compare performance to process dependent limits rather than ideals.

The treatment of waste requires these wider views in order not to overlook potentials for overall gains in fruitless pursuit of ideals.

## C.2 IMPLEMENTATION OF PERFORMANCE CRITERIA

The disjoint discussions of effort, expense and waste provide alternative criteria for judging energy systems. They are to be joined here in a discussion of substitution.

Substitution can simply be considered as the choice of an alternative to replace a previously chosen one. It was seen in Figures 1.2.1-1 and Figure 1.2.1-2 of Chapter 1 that consumers and producers attempt to achieve their various objectives by combining energy inputs, material goods and services. Some obvious areas for substitutions are technologies (extraction processing, manufacturing, and final use), energy sources, materials for energy, dollars for energy, and comfort for other wants. Substitution is such a general concept that the three modes of conservation described above can be expressed in terms of it. Substitution of plentiful for scarce fuels is an obvious one. Increasing energy efficiency entails a substitution of energy-using hardware. Curtailing energy end-use is a substitution of consumer wants for one another. The status quo can serve as the base choice in any substitution.

First-cost, life-cycle cost and net-energetics can be used at any level of the resource chain to evaluate potential substitutions. They are all essentially examples of cost-benefit analysis. In the absence of detailed information all along the resource chain, there seems no better way to illustrate the point than a hypothetical example. The latter presents various substitutions of processes. As mentioned above, this is only one area in which they may occur.

As depicted in Figure C.2-1, consider energy resources, ALPHA-18 and ALPHA-19 that can be gotten out of the ground by:

(E1) Extraction 1 (deep room mining)

(E2) Extraction 2 (open pit mining).

Once out of the ground, ALPHA-18 or ALPHA-19 is used by a firm (at the site) in combination with labor, capital and other materials in two processes:

(P1) Process 1 (chemical reduction: cracking)

(P2) Process 2 (physical reduction: grinding)

to produce BETA.

BETA is used by a manufacturing firm (also at the site) to produce GAMMA by either:

(M1) Manufacture 1 (assembly line)

(M2) Manufacture 2 (total product produced by each worker).

Local consumers use GAMMA by either:

(C1) Consume 1 (internal)

(C2) Consume 2 (external)

to obtain PLEASURE from C1 or KNOWLEDGE from C2. This is schematically represented in Figure C.2-1.

The possible substitutions are ALPHA-18 vs ALPHA-19, E1 vs E2, P1 vs P2, M1 vs M2, C1 vs C2, and using ALPHA-18 and ALPHA-19 for entirely different purpose.

It is assumed that the techniques in each category use the same amounts of labor and other materials, but a different "machine" and different amounts of energy. Hypothetical data for these processes in terms of the performance criteria are given in Table C.2-1. The energy efficiency column measures the BTU's per dollar of output of the firm. As noted above, a true net-energetics would take into account all the indirect as well as direct energy. This point is ignored in the example. The stars (\*) represent the efficient choices by each criterion in the five two-row comparisons. These are called CATEGORY CHOICES. In cases where the decision - maker would be indifferent, there is no star.

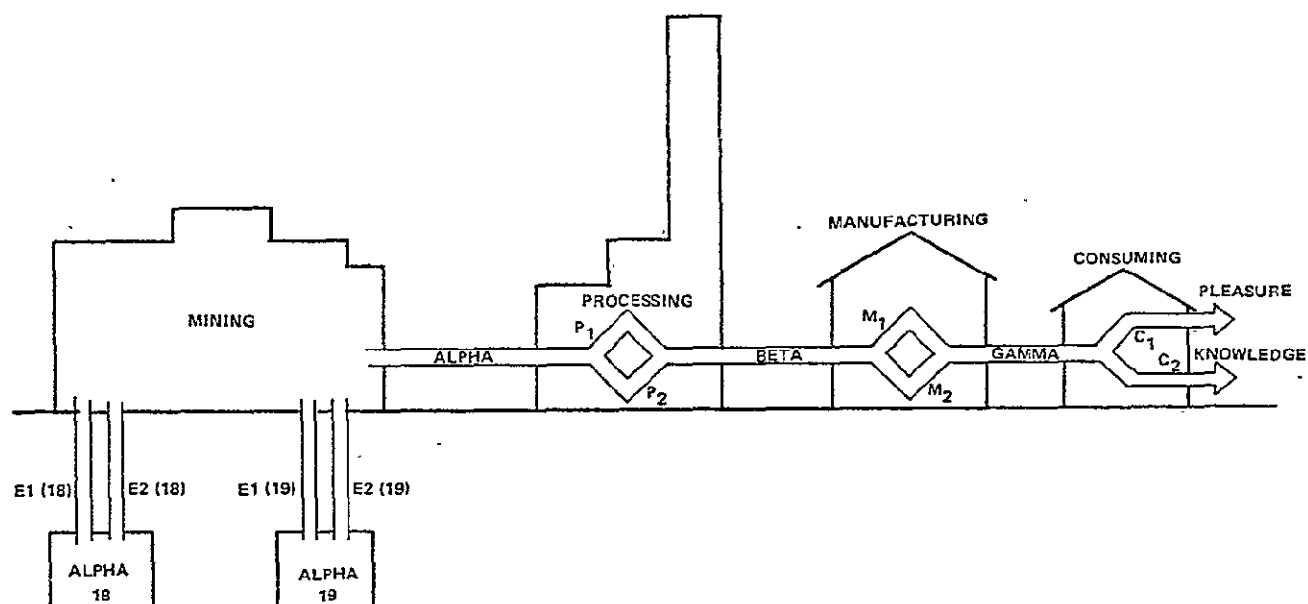


FIGURE C.2-1. SCHEMATIC DIAGRAM OF POTENTIAL SUBSTITUTION

TABLE C.2-1. MEASURING RODS FOR ACTIONS

ACTIVITY	FIRST-COST \$ thousands	LIFE-CYCLE COST \$ thousands	ENERGY EFFICIENCY BTU/\$ OUTPUT BTU (THOUSANDS)
E1 (18)	*100	*350	*10
E2 (18)	150	400	12
E1 (19)	200	280	14
E2 (19)	200	*260	*8
P1	90	*100	5
P2	*80	110	*4
M1	50	*80	*1
M2	*30	90	9
C1	10	25	7
C2	*5	25	7

C-14  
The data in Table C.2-1 have been arranged so as to include cases where the criteria yield the same choice and different choices. The differences depend on the relationships of the price of the machine to its energy operating costs over time, and the life-cycle cost to the number of BTU's used per dollar output. The first is based on empirical facts. Included are positive, constant and negative relationships. The second is based on the relationship of dollars to BTU's, and is discussed below. Again positive, constant and negative relationships are displayed.

In order to discuss substitution, the \* choices E1(18), P2, M2, C2 according to the first cost measure will be considered the status quo choices. CROSS-CATEGORY SUBSTITUTIONS are made among the various categories in the resource chain. Potentials for substitutions may exist at each level, but some are better than others. It is assumed that large numbers of substitutions cause economic disruption. They then may be ranked in terms of each non-status quo criterion. Table C.2-2 presents the savings according to each. The change from E1(18) to E2(19) is the greatest LCC-saving substitution. According to energy efficiency, however, the M1 to M2 substitution presents the greatest savings. The substitution of C2 for C1 does not benefit or hurt the decision-maker.

A crucial element in an accounting system such as net-energetics is a proper treatment of the system boundary. This includes processes within the boundary and flows across it. Serious problems arise in utilizing the accounting system as a relative measure of performance when systems differences are not properly recognized and weighted in the comparison.

Problems arise in specifying the system boundary. The level of generality can be chosen in many different ways, as mentioned above. The problems include double accounting of indirect energy flows, unequal assignment of boundaries to alternate systems, and excess generality. The last alters the relative size and assignments of aggregate flows among systems. The simplest systems such as a generator or pump have well-defined boundaries for measuring direct efficiency, life-cycle costs, and even energy imbedded in their manufacture. All the boundaries begin to become ill-defined as more levels of accounting are included.

The flows crossing the boundaries of a system present two problems in measurement. The energy flows themselves are simple to measure and compare. The imbedded flows into or out of the system are much more difficult to assess. Also, the charging of imbedded flows to downstream users often requires arbitrary partitioning of the flow. In comparing alternate systems as an assessment of their relative merits, it is necessary to weight the different forms and amounts of input and output flows. In particular the character and impact of waste streams or by-product streams may differ significantly.

Since the distribution of an imbedded quantity like energy with respect to number of units is apt to be very skewed, the energy-weighted average and the dollar weighted average would give different rates than the gross ration. The most important addition to energy accounting in the trend toward net-energetics is the valuation of waste and by-product and recycling streams in terms of their potential value impacts. The flow of impacts is like a flow of costs or charges back into the process. This is an internalization of those things such as pollution which used to be strictly outside the system boundary.

TABLE C.2-2 GAINS FROM SUBSTITUTION

SUBSTITUTION	LIFE CYCLE SAVINGS (\$ x 10 <sup>3</sup> )	ENERGY SAVINGS (BTU x 10 <sup>3</sup> )
E1 (18) to E2 (19)	350 - 260 = 90	10 - 8 = 2
P2 to P1	110 - 100 = 10	STAY AT P2
M2 to M1	90 - 80 = 10	9 - 1 = 8
C2 to C1	INDIFFERENT	INDIFFERENT

In comparing alternate systems, the last point of difference is the activity within the boundary. There are lost potentials, impacts, and charges (or credits) to the process within that boundary.

The exact application of an energy accounting method is going to require considerable experience and testing of methods for assigning boundaries and weighting differences in input flows, output flows, and opportunities. As an example, the reader needs only to recall the potential system boundary charge associated with waste heat utilization by power plants.

The essential point of the example is that most energy systems in the real world are chosen on a first cost basis. It appears to be difficult to get the average citizen to consider life-cycle costing and energy efficiency criteria. The latter two have the potential to alleviate some of the U.S. energy problems.

The relation of dollar costing to net-energetics is basically tied to the mapping between dollars and BTU's. Life-cycle cost as well as first-cost may yield energy choices that are detrimental in a net-energetics sense. This is principally caused by the problems with energy prices as discussed in Section C.1.2 above. It has been warned, however, that the energy shortage may be a passing phenomenon. It follows that a BTU theory of value may place too much importance in the future on a commodity that is relatively scarce today. This latter viewpoint will essentially obviate the need for net energetics criteria. Until the energy scarcity does indeed pass, the need for alternative energy accounting methods will remain. More needs to be done specifically to determine the degree of disparity between dollar and energy measures. Of particular importance because of its previous neglect is the relation of energy prices to energy availability in the sense of the Second Law of thermodynamics.

### C.3 APPLICATION OF THE CRITERIA TO MAJOR ISSUES

The efficiency and energy accounting concepts discussed above should always be considered when planning or implementing a strategy that has wide-spread effect on energy consumption patterns. Three such programs currently being considered or in some stage of implementation are: Electrification -- the move toward an electric economy; Diversification -- the move toward several different energy sources; and National Energy Conservation -- a move toward a widespread energy conservation and oil policy in the United States. Each of these strategies involves several actions which should be analyzed and compared by application of criteria including those discussed above.

Representative actions included in the electrification strategy are conversion to coal for electric power generation; conversion to nuclear energy for electric power generation; development of electric automobiles; development of electric fixed rail transit; installation of heat pumps for space conditioning; and installation of electric furnaces for industrial applications. Justifications which are cited by proponents of electrification are that it will make use of fuels which are plentiful relative to gas and oil; electricity used correctly will imply that energy supplies be used more efficiently; adequate power generating

plant load leveling will result in more efficient use of economic resources. In light of these justifications, each of the actions included in the electrification strategy should be analyzed relative to alternative means of accomplishing the same effect. Three of the criteria which should be applied while making the analysis are energy efficiency (including net energetics), economic efficiency and examination of the creation of waste and opportunities for its use. For example, when considering the conversion to coal and nuclear energy, a net energetics study should be done which considers all of the direct and indirect energy inputs which go into the production of a unit of output -- electricity. Some studies have indicated that from the viewpoint of this criterion, these alternatives do not appear to be attractive relative to oil or gas-fueled plants. When the second energy performance criterion is applied, however, the use of these alternate fuel sources becomes more attractive. Finally, an examination of the waste created when primary energy is converted to electricity reveals that apparently more energy is wasted (2/3 to cooling water) than where primary energy is used directly. This introduces the concept of looking at the entire system from the mine or well to the final end use point. The electric car and heat pump illustrate this. If the energy is traced from its source through the various phases of use and conversion from a net energetics standpoint, a very good case can be made for the electric heat pump as opposed to direct use of primary energy. For the case of the electric car, an analysis employing net-energetics and life-cycle costing may indicate steps in the energy use chain where development will lead to higher overall energy and financial efficiencies with the added advantage of fuel substitution and electric generating plant load-leveling. If means for using the waste heat from power plants can be devised, the overall efficiency of the entire system (both energy and economic) will be greatly increased and the biggest potential drawback to electrification will be alleviated.

On the other hand, some of the actions (e.g. rapid transit) contemplated in the electrification strategy may not be attractive from a net-energetics and/or an economic standpoint. At any rate, each action must be analyzed in light of all the other actions using a net-energetics and life-cycle costing approach.

Some of the actions which are included in the diversification strategy are the development of solar energy, geothermal energy, oil from oil shale and energy from ocean thermal gradients. Conversion to coal and nuclear are also actions which are considered in the diversification strategy and overlap with electrification.

Each of these actions is a prime example of those which should be thoroughly examined from a net-energetics and life-cycle costing standpoint. In fact, such analyses have been carried out on some of them. They will not only indicate whether a given action is feasible, but will also indicate the stages in the energy use chain where increased technological development is needed and should be concentrated. A net-energetics analysis for each of these alternate energy sources would consider all of energy inputs that are required to obtain a unit of output. Economic analysis would have to consider the net economic cost of producing a unit of output and weigh this against the cost of producing the same output by conventional means. It is difficult to assign an energy or financial value to the utility of avoiding having "all of your eggs in one basket" and making use of all available energy sources.



National Energy Conservation proposes basic actions which should be taken "To increase domestic energy supplies and availability; to restrain energy demand; to prepare for energy emergencies; and for other purposes." Six of the basic actions which might be proposed are establish a price ceiling on oil; restrict gasoline demand to 1974 levels; establish mandatory automobile efficiency; establish industrial efficiency improvements; establish energy labeling and efficiency standards for consumer products other than automobiles; conversion from oil or gas to other fuels. Again the methods of net-energetics and life-cycle costing should be applied to each of these actions and to the overall strategy. For example, establishment of energy efficiency standards for automobiles may lead to increased use of energy intensive materials such as aluminum and plastic and result in increased use of energy. From a life-cycle cost viewpoint, lighter cars (if this is one way increased efficiency is achieved) may end up costing the consumer more in operating costs in the long run because of less durability. A more subtle point is the question of how the consumer will make use of any saving that might accrue from energy savings. If he spends it on energy intensive activities, the action may turn out to be counter-productive. The same principles can be applied to industrial efficiency improvements and increased consumer product efficiency. The means of achieving these improvements must be analyzed in light of their energy and monetary costs to determine if indeed a savings will be realized. The price ceiling on oil may also lead to increased energy consumption as well as higher costs in the long run. This action may impede development of alternate sources or increase oil use for other than electrical generation. It appears that some of these actions may be at odds from a net energetics standpoint and a need for such an analysis which considers all of the actions together is strongly indicated.

### C.3.2 INPUT-OUTPUT ANALYSIS

Input-output analysis is a descriptive model of an economy. Its appeal is that it exhibits the relationship between the volume of output generated by an industry and the size of the inputs going into that production. It is an important tool because it permits the tracing of the flows of inter-industry transactions as well as the composition of gross national product.

Fundamental to the understanding of the input-output flow is the distinction between the total output produced by an industry and the final demand for the products of an industry. Gross national product, GNP, as defined by the Department of Commerce, is either computed as the sum of final product flows or as the sum of the incomes generated in GNP production. Components of final product flows are personal consumption expenditures, gross private domestic investment, net exports of goods and services, and government purchases of goods and services. Lumped together these define aggregate demand. On the other side, some of the incomes generated in the production of GNP are compensation of employees, proprietor's income, rental income of persons, corporate profits and inventory valuation adjustment. One way of displaying these two equivalent definitions of GNP is given in Table C.3.2-1. Notice that the box that represents producer to producer sales of goods and services used in production is blank. These sales are already included in the value of the final products that add up to the total GNP.

TABLE C.3.2-1. COMPONENTS OF GNP

		Final Production				
		Producers	Persons	Investors	Foreign	Government
<u>INCOMES</u>	Producers		Personal	Gross	Net	Government
			Consumption	Private	Exports	Purchases of
	Owners of Business & Cap.	Employee Compensation	Expenditures	Investment		Goods and Services
		Indirect Business Taxes				
	Government					
GNP						

However, since industry sales to industry are of interest we can isolate these by expanding the blank box. Table C.3.2-2 displays the input-output flows as well as the components of GNP. A row shows the sales of that industry to each of the other industries as well as to the final markets. Total output is thus the sum of industry sales to other industries and sales to final markets. Final demand is only the sales to final markets. A column shows the industrial sources of goods and services used in production as well as the incomes generated by the industry for the column. Note also that value added is the term used to summarize the incomes. Given the input-output display we can then ask what information is contained in the table. There are three primary types of information:

### 1. Transaction Flows

These are the dollar value of transactions among industries. Each row shows the sales to each industry and to final markets. If  $X_j$  is the total output of industry  $j$  and  $f_j$  is the sales of industry  $j$  to final markets then:

$$X_j = \sum_i X_{ij} + f_j \quad (C-1)$$

Where  $X_{ij}$  is the sales of industry  $j$  to industry  $i$ .

### 2. Direct Requirements

Using Table C.1.1-3, each column shows the inputs that the industry named at the top of that column required from the industry named at the beginning of each row to produce a dollar of its output. Direct requirements are denoted by  $a_{ij}$  -- requirements from industry  $j$  for industry  $i$  to produce a dollar of total output. The definition of  $a_{ij}$  is given by:

$$a_{ij} = \frac{X_{ij}}{X_j} \quad (C-2)$$

### 3. Total Requirements

Total requirements are the sum of direct and indirect requirements needed to produce one dollar of final demand. An example of an indirect requirement would be the iron ore needed for the production of steel which is used in automobile production. Since automobile production does not consume iron ore directly, the entries in the transaction matrix and direct requirement tables would be zero. How are total requirements computed?

$$X_j = \sum_i a_{ij} X_j + f_j \quad (C-3)$$

is the equation which related total output to sales of final outputs  $f_j$  and to sales to intermediate production  $\sum_i a_{ij} X_j$ .

TABLE C.3.2-2. INPUT-OUTPUT FLOWS

		Producers			Final Markets		
		Agriculture	Mining	Construction	Manufacturing	Persons	Government
PRODUCERS	{	Agriculture					
		Mining					
		Construction					
		Manufacturing					
		Employees					
VALUE ADDED	{	Owners of Business & Capital					
		Government					GNP

Writing this relationship in matrix form we have:

$$\underline{x} = A\underline{x} + \underline{F} \quad (C-4)$$

Where  $\underline{x} = (X_1, \dots, X_j)$ ,  $A = (a_{ij})$ , and  $\underline{F} = (f_1, \dots, f_j)$ .

An equivalent form is given by:

$$(I-A) \underline{x} = \underline{F} \quad (C-5)$$

To find total requirements solve the equation to find outputs needed to meet final demands  $\underline{F}$ .

$$\underline{x} = (I-A)^{-1} \underline{F} \quad (C-6)$$

The total requirements are the column entries in the  $(I-A)^{-1}$  matrix.

Remembering that  $GNP = \sum f_j$ , we can define an industry's share of GNP,  $W_j = f_j/GNP$ . If one assumes the  $W_j$ 's are fixed then given a projection of GNP, say  $\hat{GNP}$ , an estimate of final demand for industry  $j$  is given by:

$$\hat{f}_j = W_j \hat{GNP} \quad (C-7)$$

The consistency of the estimated GNP can be evaluated by substituting  $\hat{f}_j$  into (C-6).

$$\hat{\underline{x}} = (I-A)^{-1} \hat{\underline{F}} \quad (C-8)$$

If the output derived in  $\hat{\underline{x}}$  is greater than the estimated supply (crude petroleum e.g.) the GNP estimate is too large. An alternative to lowering  $\hat{GNP}$  would be to change the  $W_j$ 's and/or alter the direct requirements matrix  $A$ .

If  $\underline{L}$  is a vector of total labor employed by all industries, we can compute the ratio of labor to output by

$$l_i = l_i/X_i \quad (C-9)$$

Using (C-9) the dollar transactions matrix can be converted to a labor transactions' matrix by multiplying (each entry in) the  $i$ th row of the transaction matrix by  $l_i$ . A similar procedure can be utilized to convert the transactions' matrix into an energy transactions' matrix.

#### C.4 CRITERIA APPLIED TO A HELIOSTAT SOLAR PLANT

The Solar steam generation is compared with nuclear, coal, and oil. A typical 100 Mwe solar plant has the following dollar (1973) and material requirements [PI-75-10]. It is considered for the southwestern U. S.

Land (600 Acres at \$1000/Acre)	\$ 600 (Thou.)
Structures & Facilities	3,800
Heliostats (1 Km <sup>2</sup> Coll. Area at \$30/m <sup>2</sup> )	30,000
Central Receiver/Towers (2x260 mTWR at \$2M/TWR)	4,000
Thermal Storage Materials 8 Tanks (6 Hrs at \$15/KW Hr.)	9,000
Heat Exchanger	1,000
Turbine Plant Equipment	6,000
Electric Plant Equipment	1,500
Misc. Plant Equipment	400
Cooling Towers	<u>1,200</u>
Total	57,500
Contingency	3,000
Spare Parts	700
Indirect Cost	<u>4,000</u>
Total	65,000
Interest (8%) During Construction	<u>8,300</u>
Total	73,500

Recall it is desired to compare the solar method of steam generation for a 100 Mwe with nuclear (LWR), coal and oil. Considering it would take approximately six years or until 1981 for their construction, all data will be considered in 1981 dollars. The first cost of the solar is

converted from 1973 to 1981 by compounding at 5.5% for eight years. The operating and management (O&M) costs of three mills per kilowatt-hour [PI-75-10] is also converted to 1981; a load factor of 0.65 was used. These values with those for nuclear (LWR) et al. are presented in Table C.4-1. On a first cost basis, the oil plant is best by a considerable margin.

For evaluation of the 20 years life cycle cost (LCC), an inflation rate of 5.5% was used to get escalated values for the  $C_n$  values in Equation C.1.2-1; the discount rate was  $r=10\%$ . On the LCC basis the nuclear plant is seen to be best.

#### C.4.1 NET ENERGETICS

In the above analysis, for solar systems, the economy improvement from mass production was not considered. By these improvements, their LCC is expected to be competitive with the others. In anticipation of that improvement, a net energetics analysis is presented in this section. Its major material requirements are given in Table C.4.1-1.

The energy delivered by the 100 Mwe solar plant was obtained using a load factor of .56 (5 week/year for maintenance) [Spencer-75]; per year it is  $1.67 \times 10^{12}$  BTU. By using a rate of return over the 20 years and equating it to the total energy input (from Table C.4.1-1), the energy rate of return  $r$  for this solar system can be determined. By Equation C.4.1-1, this  $r$  was determined to be 28 percent. The last term considers the energy salvage value of the scrap; the scrap aluminum is considered to have a 90% energy saving of the primary, the steel 33% of the primary. [PFE-74]

$$5.86 \times 10^{12} \text{ BTU} = \sum_{k=1}^{20} \frac{1.67 \times 10^{12}}{(1+r)^k} + \frac{1.77 \times 10^{12}}{(1+r)^{20}} \text{ BTU's} \quad (\text{C.4.1-1})$$

TABLE C.4-1. ESTIMATED 1981 GENERATING COST FOR 100 MWE STEAM  
ELECTRIC POWER PLANTS

<u>1981 Cost (\$ Millions)</u>	<u>Solar</u>	<u>LWR<sup>a</sup></u>	<u>Coal<sup>a</sup></u>	<u>Oil (lows)<sup>a</sup></u>
First cost	\$173	54.4	50.8	37.4
Fuel*	0	1.4	3.1	14.0
O&M	4	.4	.63	.3
LCC (20 yrs)	223.3	77.3	98.1	217.1

<sup>a</sup>[AEC-73]: these values are deemed to be obsolete (pre-embargo)

\*Calculated from referenced data using an annual inflation factor of 0.05

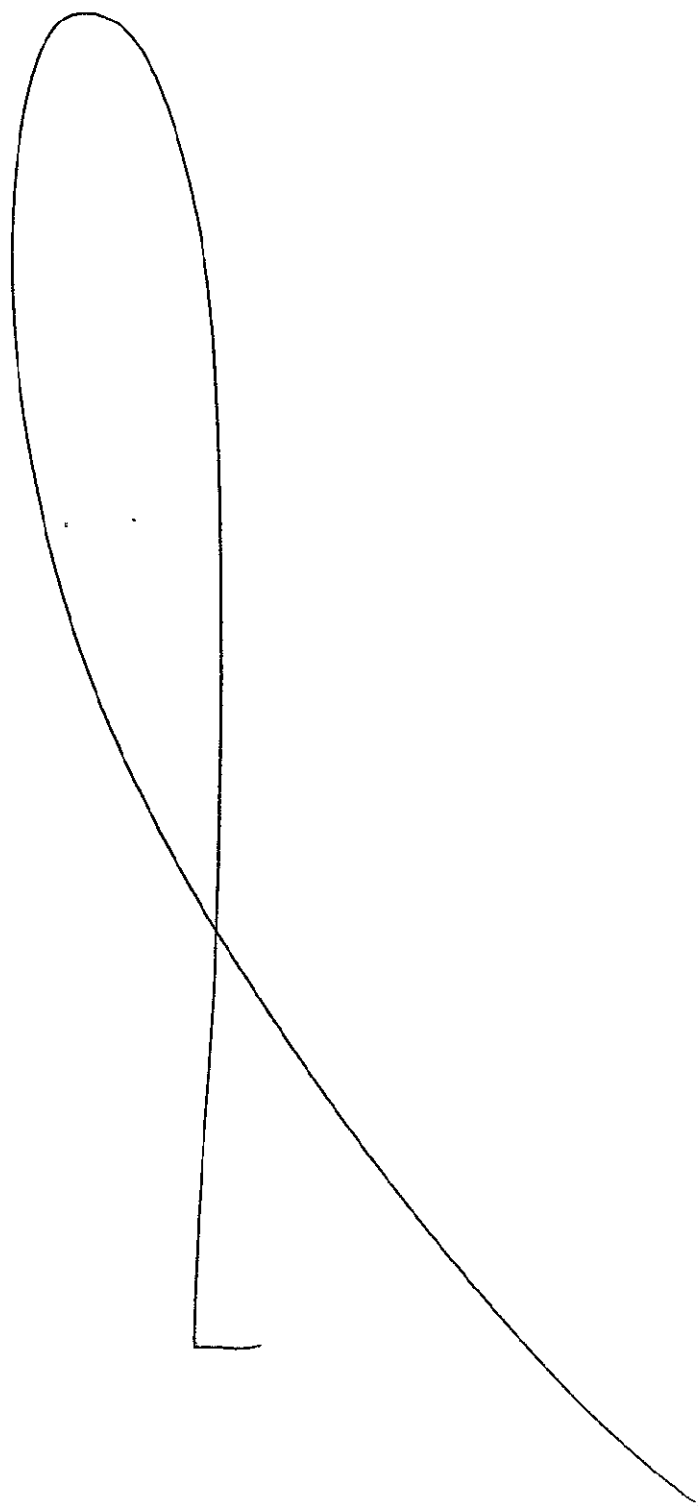
TABLE C.4.1-1. MATERIAL REQUIREMENTS FOR A 100 MWE SOLAR PLANT

	<u>TONS<sup>a</sup></u>	<u>ENERGY<sup>b</sup> (BTU x 10<sup>10</sup>)</u>
Steel	25,800	516.0
Concrete	17.7	.004
Aluminum	961	7.5
Glass	63	<u>62.5</u>
Total		586.0

<sup>a</sup>[PI-74-10]

<sup>b</sup>[TRW-74]





## APPENDIX D. REPORT OF THE ENERGY INDUSTRY TASK GROUP

### D.1 INTRODUCTION

Specific sectors included within the energy industry are electrical power production and transmission, oil production and processing, natural gas production, uranium mining and production and coal mining. Also included are a number of developing technologies such as natural gas liquefaction, coal gasification, coal liquefaction, shale oil development and solid waste gasification. Basically each of the energy industries are to some degree in direct competition in supplying energy to industrial, residential and commercial consumers, although features of individual sources may preclude particular fuels in specific applications.

As these industries are in fact process or extraction industries rather than final consumers, conservation actions aimed at reduced demand will not generally apply. Primary emphasis will be placed on alternate actions which provide substitutes for scarce fuels or increase process efficiency.

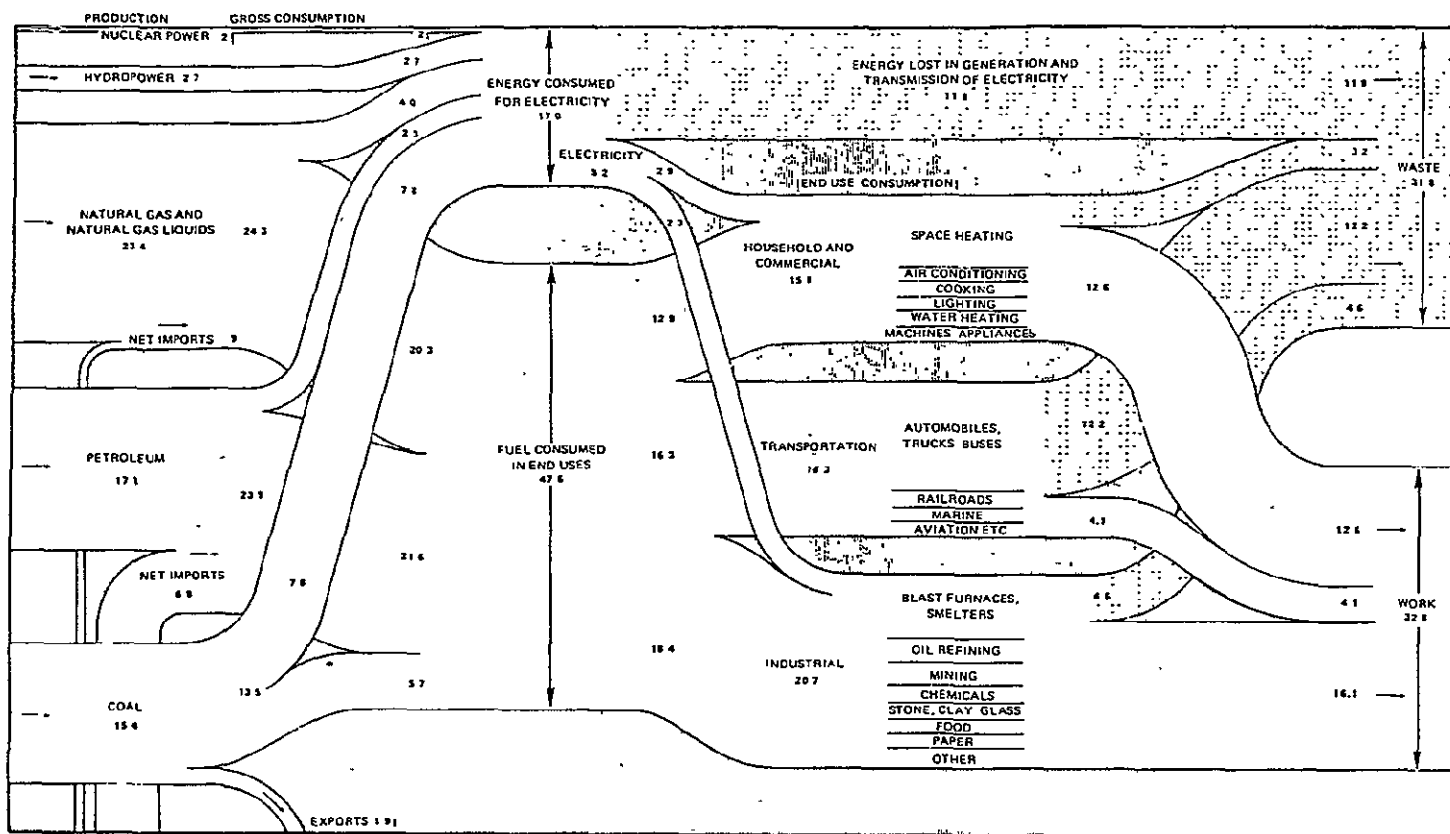
Preceding the discussion of conservation actions, potentials and impacts is the description of the energy industry in historical perspective. It is felt that the past and present have significant influence on what future actions can or will be, especially in the near term (1985). Section D.2 of the report begins with a description of the overall energy industry from 1950. It continues to examine the detailed operations of all the fossil fuel industries and the electricity industry. Finally, a study of developing technologies in many of these industries describes their present status and indicates their future potentials.

Although the basic partition of Section D.2 is according to industries, the reader will note that it covers the directed resource flow in Figure D.1-1 up to Transmission, Distribution and Storage. (Industry, Transportation and Residential/Commercial will carry the flow to its end.) Figures D.1-1 and D.1-2 are thought to be a good characterization of the energy system. From them can be depicted areas for possible conservation. Section D.3 deals with conservation actions. The actions are enumerated and their impacts assessed in Section D.4.

### D.2 PRESENT ENERGY SYSTEMS

The impetus of this section stems from the need to characterize the

TABLE D.1-2. THE FLOW OF ENERGY THROUGHOUT THE ECONOMY [MITRE-72]



FLOW OF ENERGY through the U.S. system in 1970 is traced from production of energy commodities (left) to the ultimate conversion of energy into work for various industrial end products and waste heat (right). Total consumption of energy in 1970 was  $64.6 \times 10^{15}$  British thermal units. (Adding nonenergy uses of fossil fuels, primarily for petrochemicals, would raise the total to  $68.8 \times 10^{15}$  Btu.) The overall efficiency of the

system was about 51 percent. Some of the fossil fuel energy is consumed directly and some is converted to generate electricity. The efficiency of electrical generation and transmission is taken to be about 31 percent based on the ratio of utility electricity purchased in 1970 to the gross energy input for generation in that year. Efficiency of direct fuel use in transportation is taken as 25 percent, of fuel use in other applications as 75 percent.

ORIGINAL PAGE IS  
OF POOR QUALITY

whole energy situation in the United States. Table D.2-1 gives the total energy consumption along with population and GNP from 1947-73. The positive correlations among these variables are evident. The distribution of consumption by sector is given in Table D.2-2. It depicts a fairly even distribution. The decline in the percent of energy used in the Household/Commercial sector is somewhat misleading in that the transition to electricity lowers direct usage in this sector and is charged to electric generation. Table D.2-3 gives production for the years 1947-71 by major sources. The difference between consumption and production is made up by imports. In Table D.2-4, we see that oil and gas imports as a proportion of U. S. consumption are on the rise. Coal is a negative import (export). Imports grow because the gap between domestic consumption and production grows. Since demand exceeds supply there is an upward pressure on prices. This is shown in a partial way by oil and coal prices in Table D.2-5 for selected years. Since fossil fuels dominate the energy situation, we proceed with them directly.

### D.2.1 FOSSIL FUEL INDUSTRIES

Production rates are shown in Table D.2.1-1 for coal, oil and natural gas. New reserves are also listed for both oil and gas. The rate at which new reserves are added for both fuels can be seen to have dropped significantly below production rates over the past several years. Such a trend over an extended period of time could only have led to the current problems in energy shortfall. The present situation for each of the major fossil fuels is presented below:

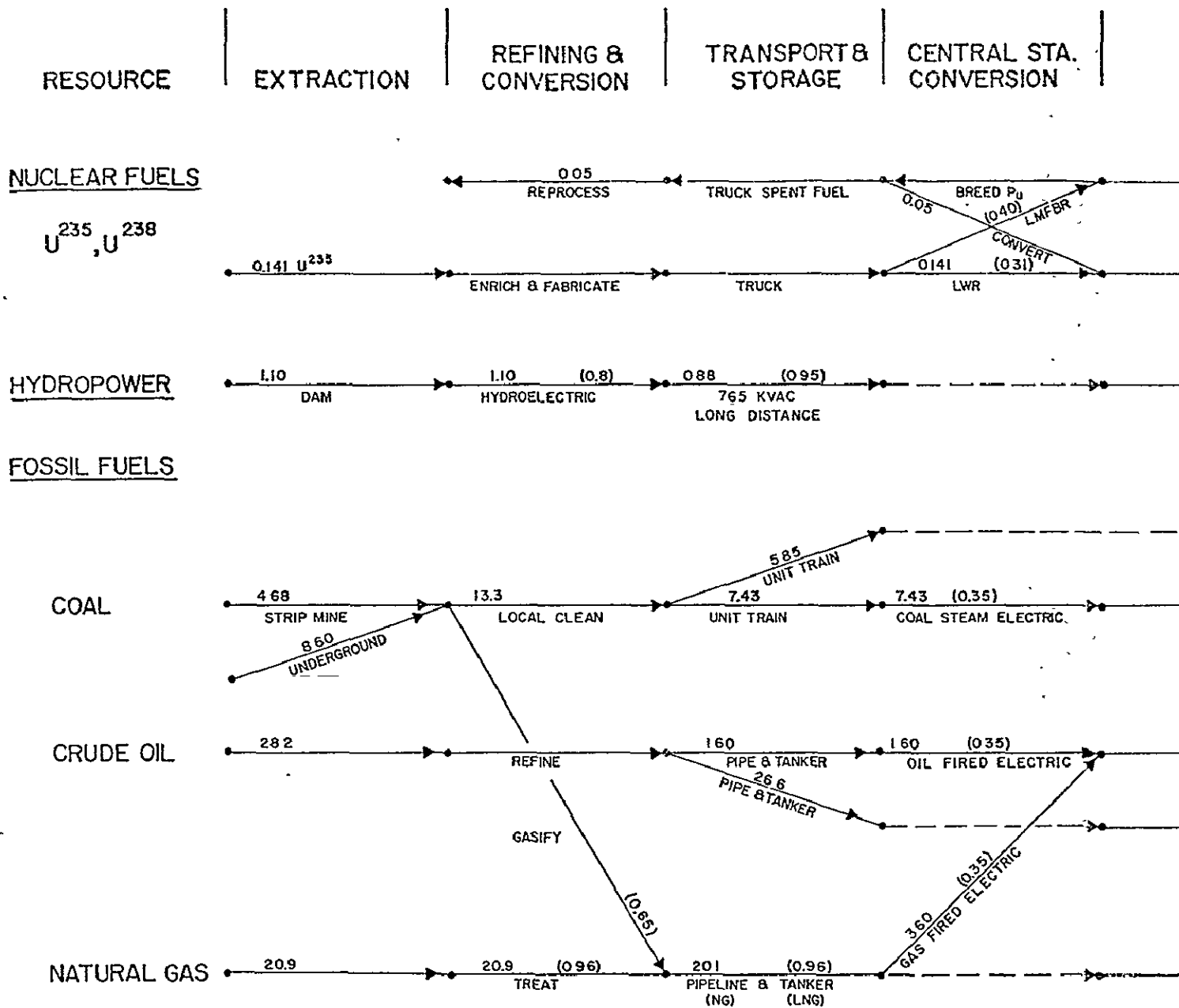
#### Petroleum

The development of the present situation in crude oil production is presented in Table D.2.1-2. Note that production capacity peaked in 1968 while production did so in 1970. Thus, while petroleum requirements have grown continuously up to the oil crisis, both production capacity and production have failed to keep pace. Refining plants and capacity are given in selected years for majors and independents in Table D.2.1-3. It is important to note the relative rate of growth between the two groups. The independents share of the production capacity has shrunk from 28% to 16% over the past 40 years. This tends to give credence to the claim of the growth of an oil oligarchy.

One of the major reasons for the growth experienced in oil usage is its ease of transport. It has been shown that there is no cheaper way, nuclear fuel excepted, to move energy over long distances than oil tankers. Tankers are owned by a variety of oil and nonoil interests; tanker rates vary over time in response to world supply and demand. Labor accounts for about 30% of the total cost and because of U. S. labor and government policies, increasing numbers of U. S. controlled tankers are registered in countries such as Panama, Liberia and Honduras. It should be noted that time spent in port is an important part of total transportation cost and should be held to a minimum. Projection of the cost of long distance

104

FIGURE D.1-1 REFERENCE ENERGY SYSTEM, YEAR 1969 [AU-75]



TOTAL RESOURCE  
CONSUMPTION:  $64 \times 10^{15}$  Btu

### NOTES

1. SOLID ELEMENT DENOTES A REAL ACTIVITY.
2. ENERGY FLOWS ARE INDICATED IN  $10^{15}$  BTU ABOVE EACH ELEMENT. CONVERSION EFFICIENCIES ARE INDICATED IN PARENTHESES.
3. INDUSTRIAL PROCESS HEAT DEMANDS INCLUDE STEEL AND ALUMINUM FUEL NEEDS OTHER THAN ELECTRIC AND COAL, AS WELL AS ALL OTHER INDUSTRIAL REQUIREMENTS
4. OIL AND GAS FIRED ELECTRIC INCLUDES STEAM AND GAS TURBINE PLANTS.

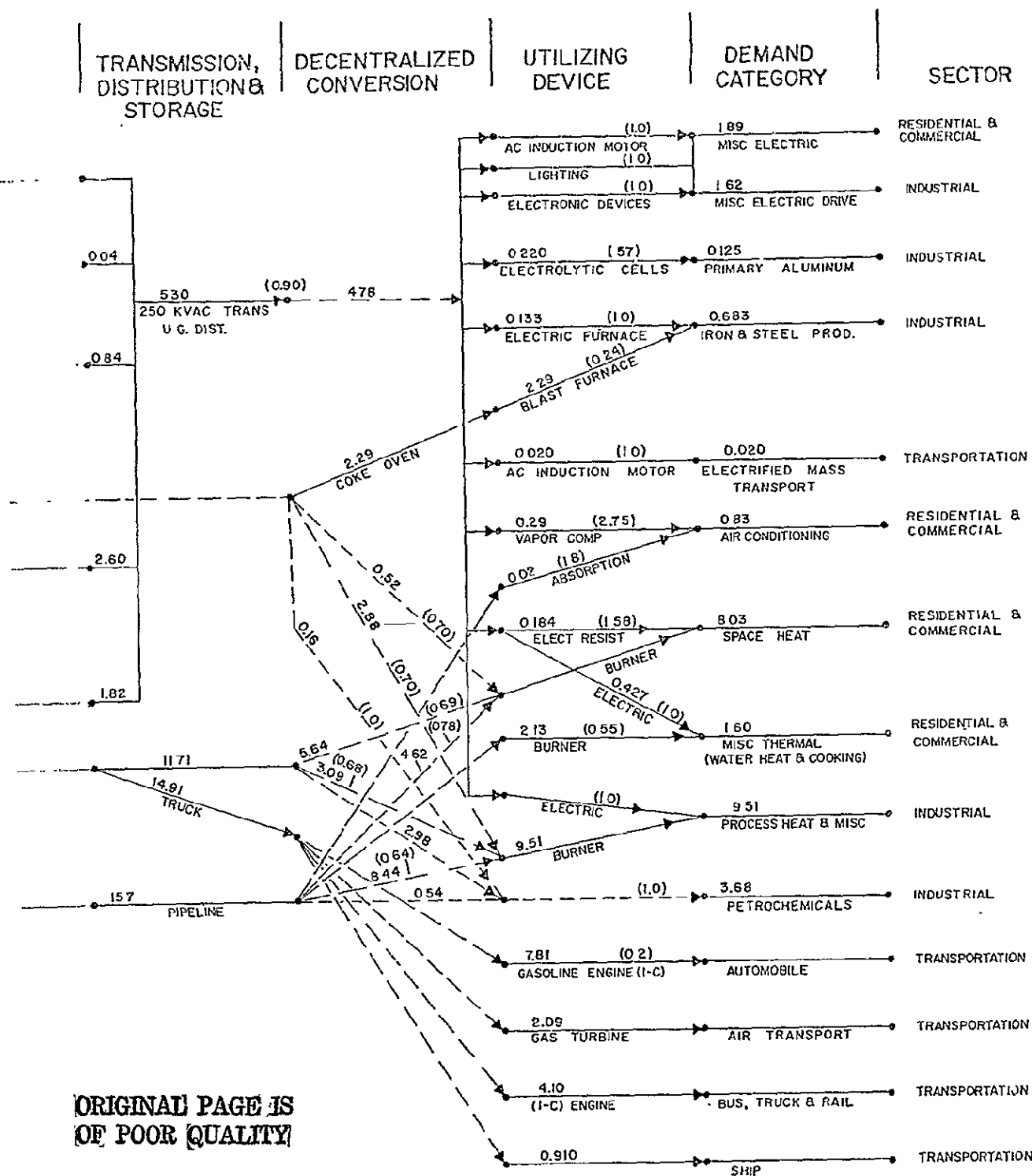


TABLE D.2-1. ENERGY CONSUMPTION, POPULATION, AND GNP, 1947-73  
[AHC-75]

Year	Gross energy consumption (quadrillion Btu)	Annual growth rate (percent)	Population (millions)	GNP (billions 1958 dollars)	Energy/1958 GNP dollar (million Btu)	Energy/capita (thousand Btu)
1947	33.0	2.7	144.1	309.9	106.4	229.0
1948	33.9	2.7	145.6	323.7	104.7	231.1
1949	31.5	-7.1	149.2	324.1	97.2	211.0
1950	34.0	11.1	152.3	355.3	95.7	223.0
1951	36.8	8.2	154.9	383.4	96.0	237.6
1952	36.5	-8	157.6	395.1	92.4	231.7
1953	37.6	3.0	160.2	412.8	91.1	234.7
1954	36.3	-3.5	163.0	407.0	89.2	222.7
1955	39.7	9.4	165.9	438.0	90.6	239.3
1956	41.7	5.0	168.9	445.1	93.5	245.9
1957	41.7	0	172.0	452.5	92.2	242.4
1958	41.7	0	174.9	447.3	93.2	238.4
1959	43.1	3.4	177.8	475.9	90.6	242.4
1960	44.6	3.5	180.7	487.7	91.4	246.8
1961	45.3	1.6	183.8	497.2	91.1	246.5
1962	47.4	4.4	186.5	529.8	89.5	254.1
1963	49.3	4.0	189.2	551.0	89.5	260.5
1964	51.2	3.8	191.8	581.1	88.1	266.9
1965	53.3	4.1	194.2	617.8	86.3	274.4
1966	56.4	5.8	196.5	658.1	85.7	287.0
1967	58.3	3.4	198.6	675.2	86.3	293.5
1968	61.7	5.8	200.6	706.6	87.3	307.6
1969	65.0	5.4	202.6	724.7	89.7	320.8
1970	67.4	3.7	204.8	722.5	93.3	329.1
1971	69.0	2.4	207.0	745.4	92.6	333.3
1972	72.3	4.8	209.6	790.7	91.4	342.9
1973	75.6	4.6	211.1	837.3	90.2	358.1

Source: Dupree and West, "United States Energy through the Year 2000," p. 13, and "Oil and Gas Journal," Mar. 25, 1974 p. 44.

TABLE D.2-2. TOTAL ENERGY CONSUMPTION BY MAJOR USER CLASS  
BY PERCENT, 1950-73 [AHC-75]

Year	Total consumption (trillion Btu's)	Industrial (percent)	Electric generation (percent)	Transportation (percent)	Household and commercial (percent)
1950	33,957	37.66	14.65	25.35	22.34
1951	36,775	39.24	14.36	25.03	21.37
1952	36,458	37.83	15.14	25.15	21.89
1953	37,586	39.20	15.67	24.49	20.64
1954	36,263	36.52	16.38	25.13	21.97
1955	39,703	36.99	16.61	24.75	21.65
1956	41,700	37.23	16.98	24.30	21.49
1957	41,706	37.07	17.58	24.53	20.83
1958	41,696	35.10	17.55	24.64	22.71
1959	43,140	35.16	18.25	24.08	22.51
1960	44,569	34.36	18.54	24.27	22.83
1961	45,319	34.03	18.84	24.24	22.89
1962	47,422	33.67	19.18	24.07	23.09
1963	49,308	33.76	19.64	24.26	22.34
1964	51,240	34.08	20.25	23.93	21.75
1965	53,343	33.23	20.76	23.83	22.18
1966	56,412	33.02	21.37	23.66	21.96
1967	58,265	31.77	21.85	24.05	22.34
1968	61,763	31.74	22.49	24.54	21.23
1969	64,979	31.30	23.48	24.29	20.94
1970	67,444	30.61	24.41	23.24	20.74
1971	68,698	29.41	25.07	24.83	20.69
1972	71,946	28.86	25.77	25.10	20.28
1973	74,742	28.96	26.28	25.07	19.69

Source: 1950-70 data from U.S. Department of Interior, "U.S. Energy Through the Year 2000," app. B, tables 1, 7, 9, 11, 12, 17; 1971 data from U.S. Department of Interior, Minerals Yearbook 1972, "Review of the Minerals Industry," table 8; 1972-73 data from U.S. Department of Interior, "News Release," March 13, 1974.

TABLE D.2-3. U. S. TOTAL PRODUCTION OF ENERGY RESOURCES BY MAJOR SOURCES, AND 1971 PRELIMINARY [SESA-73]

[In trillions of Btu]

Year	Anthracite	Bituminous coal and lignite	Natural gas, dry	Petroleum	Total fossil fuels	Hydro-power	Nuclear power	Total gross energy inputs	Percentage change from prior year
1947	1,453	16,522	5,012	10,771	33,758	1,296		35,054	
1948	1,451	15,707	5,615	11,717	34,480	1,369		35,859	+2.3
1949	1,085	11,472	5,911	10,683	29,151	1,425		30,576	-14.7
1950	1,120	13,527	6,841	11,449	32,937	1,415		34,352	+12.3
1951	1,084	13,982	8,106	13,037	35,209	1,424		37,633	+8.6
1952	1,031	12,231	8,705	13,282	35,249	1,466		36,715	-2.4
1953	786	11,981	9,116	13,671	35,554	1,413		36,967	+0.7
1954	739	10,262	9,488	13,427	33,916	1,360		35,276	-4.6
1955	655	12,080	10,532	14,445	37,722	1,360		39,082	+10.8
1956	734	13,013	11,252	15,344	40,343	1,435		41,778	+6.9
1957	644	12,800	11,885	15,346	40,675	1,422		42,098	+0.8
1958	538	10,663	12,244	14,154	37,599	1,632		39,231	-6.9
1959	524	10,581	13,361	14,662	39,128	1,551		40,681	+3.8
1960	478	10,662	14,135	14,664	39,959	1,608		41,563	+2.1
1961	443	10,308	14,691	15,185	40,627	1,656		42,283	+1.8
1962	429	10,782	15,365	15,495	42,071	1,816		43,887	+3.8
1963	464	11,712	16,271	15,741	44,188	1,768		45,956	+4.7
1964	436	12,418	17,138	15,691	45,683	1,886		47,569	+3.5
1965	378	13,017	17,652	15,930	46,977	2,059		49,036	+3.1
1966	329	13,507	18,984	16,925	49,745	2,062		51,807	+5.7
1967	311	13,904	20,087	18,100	52,402	2,347		54,749	+5.7
1968	291	13,664	21,548	18,593	54,096	2,349	130	56,575	+3.2
1969	266	13,957	22,838	18,886	55,947	2,648	146	58,741	+3.8
1970	247	15,001	24,154	19,772	59,174	2,639	229	62,033	+5.6
1971 <sup>1</sup>	221	13,933	24,871	19,559	58,584	2,833	391	61,808	-1.4

<sup>1</sup>Includes Alaska.<sup>2</sup>Denotes 1st year for which figures include Alaska and Hawaii.<sup>3</sup>Preliminary.

TABLE D.2-4. NET IMPORTS OF ENERGY AS PERCENT OF U. S. CONSUMPTION OF EACH FUEL, 1950-73 [AHC-75]

[Net exports shown as negatives]

Year	Natural gas	Petroleum and products	Coal	Total
1950	-0.42	9.06	-5.85	1.29
1951	-0.34	6.52	-12.31	1.66
1952	-0.25	7.73	-11.43	1.32
1953	-0.35	8.89	-7.96	1.21
1954	-0.26	9.62	-8.63	1.79
1955	-0.22	11.16	-12.85	1.13
1956	-0.26	12.07	-17.14	1.50
1957	-0.63	12.13	-19.74	1.10
1958	-0.91	16.40	-14.97	4.56
1959	1.09	17.40	-10.81	5.78
1960	1.17	17.46	-10.22	5.87
1961	1.63	18.77	-10.06	6.76
1962	2.83	19.85	-10.76	7.43
1963	2.70	19.25	-12.79	6.61
1964	2.81	20.08	-11.92	7.01
1965	2.75	21.38	-11.86	7.50
1966	2.70	21.28	-11.01	7.60
1967	2.72	19.10	-11.22	6.81
1968	2.94	20.78	-11.05	7.78
1969	3.31	22.24	-12.25	8.42
1970	3.51	23.10	-15.41	8.36
1971	3.87	24.63	-11.39	9.59
1972	4.20	28.22	-10.97	11.72
1973	4.16	34.61	-9.64	14.83

<sup>1</sup>Electricity imports are generally positive but the amounts are small, though not negligible. The net balance in electric energy trade usually falls below 1 percent of U.S. consumption.

Source: All imports for 1950-70 calculated from: U.S. Department of Interior, "United States Energy Through the Year 2000," app. B, tables 20, 21, 27. Petroleum data: for 1971-72 calculated from American Petroleum Institute, "Annual Petroleum Statistics," 1956-72; for 1973, calculated from "Survey of Current Business," April 1974, pp. S-35. Natural gas data: for 1971 calculated from Department of Interior, "Minerals Yearbook, 1971," p. 765. Coal data: for 1971 calculated from U.S. Department of Interior, "Minerals Yearbook-1971," pp. 374, 493; for 1972, calculated from U.S. Department of Commerce, "Survey of Current Business," September 1973, pp. S-35, for 1973 calculated from "Survey of Current Business," April 1974, pp. S-34; 1972-73 natural gas and total from U.S. Department of Interior, "News Release," March 13, 1974.

ORIGINAL PAGE IS  
OF POOR QUALITY



TABLE D.2-5. PRICES OF COAL AND CRUDE OIL 1955-72 [AHC-75]

[Current dollars]

Year	Coal price		Oil price		Relative price of coal col (2)/ col. (4)
	Per ton <sup>1</sup>	Per British thermal unit	Per barrel	Per British thermal unit	
(1)	(2)	(3)	(4)	(5)	(6)
1955	\$4 51	\$0 18	\$2.77	\$0 50	\$1.63
1960	4.72	.19	2.88	.52	1.64
1965	4.49	.18	2.86	.52	1.57
1966	4.58	.19	2.88	.52	1.57
1967	4.62	.18	2.92	.53	1.58
1968	4.72	.19	2.94	.53	1.61
1969	5.04	.20	3.09	.56	1.63
1970	6 30	.25	3 18	.58	1 98
1971	7.07	.28	3.36	.61	2.10
1972	7.56	.30	3.39	.61	2.26

<sup>1</sup> Prices are average values of bituminous coal for underground and surface mines at the source.

Source: National Petroleum council, U.S. Energy Outlook: Coal Availability, p. 139 and Bureau of Mines.

TABLE D.2.1-1. FOSSIL FUEL PRODUCTION AND PROVED RESERVES, 1950-73, IN ORIGINAL UNITS [AHC-75]

Year	Petroleum <sup>1</sup> (10 <sup>9</sup> bbls)				Natural gas (10 <sup>12</sup> cubic feet)				Coal <sup>2</sup> (10 <sup>6</sup> short tons) production
	Production	Reserves added	Total reserves	Reserves/production	Production	Reserves added	Total reserves	Reserves/production	
1950	2,171.2	3,328.7	29,536.1	13.60	6.86	11.98	184.58	26.93	560.39
1951	2,481.4	5,137.9	32,192.6	12.97	7.92	15.97	192.76	24.33	576.34
1952	2,541.6	3,306.1	32,957.2	12.97	8.60	14.27	198.63	23.12	507.42
1953	2,614.6	4,040.1	34,328.8	13.15	9.19	20.34	210.30	22.89	488.24
1954	2,557.9	2,980.4	34,805.2	13.61	9.38	9.56	210.56	22.46	470.81
1955	2,739.7	3,385.2	35,450.7	12.94	10.06	21.90	222.48	22.11	490.83
1956	2,897.9	3,784.1	36,337.0	12.54	10.85	24.72	236.48	21.80	579.77
1957	2,911.4	2,567.2	35,987.8	12.36	11.44	20.00	245.23	21.44	518.04
1958	2,714.3	3,466.4	36,739.9	13.54	11.42	18.90	252.76	22.13	431.62
1959	2,868.5	4,370.2	38,241.7	13.33	12.37	20.60	261.17	21.11	432.68
1960	2,902.8	3,072.5	38,429.3	13.24	13.02	13.90	262.33	20.15	434.33
1961	2,973.9	3,352.3	38,807.6	13.05	13.38	17.17	266.27	19.93	420.42
1962	3,020.3	2,913.4	38,700.7	12.81	13.64	19.48	272.28	19.96	439.04
1963	3,109.0	3,052.2	38,644.0	12.43	14.55	18.16	276.15	18.98	477.20
1964	3,180.3	3,273.5	38,737.1	12.18	15.35	20.25	281.25	18.32	504.18
1965	3,241.6	3,880.4	39,375.9	12.15	16.25	21.32	286.47	17.63	526.95
1966	3,452.9	3,858.1	39,781.1	11.52	17.49	20.22	289.33	16.54	546.82
1967	3,682.1	3,891.9	39,990.9	10.86	18.38	21.80	292.91	15.94	554.88
1968	3,826.0	3,140.3	39,305.2	10.27	19.37	13.70	287.35	14.83	556.71
1969	3,931.3	2,401.1	37,775.0	9.61	20.72	8.36	275.11	13.28	570.93
1970	4,123.4	1,996.5	46,704.3	11.08	21.96	37.20	290.75	13.24	612.61
1971	4,071.7	2,665.4	45,366.3	11.12	22.08	9.83	278.81	12.63	560.92
1972	4,037.4	1,566.1	43,126.0	10.68	22.51	9.63	266.08	11.82	597.24
1973	3,926.2	2,554.7	41,754.5	10.63	22.61	6.80	249.95	11.05	597.73

<sup>1</sup> Includes crude oil, natural gas liquids, and lease condensates.<sup>2</sup> Coal production figures include bituminous, anthracite and lignite. Coal reserves are so large as to create no constraint on production.<sup>3</sup> Includes 10,000,000,000 barrels of oil and 26 trillion cubic feet of gas added from North Slope Alaska.

Source: Petroleum data: for 1950-59, American Petroleum Institute, "Petroleum Facts and Figures-1971," p. 111; for 1970, "Oil and Gas Journal," Apr. 5, p. 38; for 1971, "Oil and Gas Journal," Apr. 3, 1972, p. 18, for 1972, "Oil and Gas Journal," Mar. 26, 1973, p. 52; for 1973, "Oil and Gas Journal," Apr. 1, 1974, pp. 42-44. Natural gas data: for 1950-72, from "American Gas Association Monthly," May 1973, p. 12; for 1973, "Oil and Gas Journal," Apr. 1, 1974, pp. 42-44. Coal data: for 1950-72, U.S. Department of Interior "U.S. Energy Through the Year 2000," app. B, table 4; for 1971, "Survey of Current Business," February 1974, p. 5-34; for 1972-73, "Survey of Current Business," April 1974 p. 5-34.

TABLE D.2.1-2. REFINERY PLANTS AND CAPACITY, BY MAJORS AND INDEPENDENTS, 1930, 1940, 1950, 1957, and 1972 [AHC-75]

	1930	1940	1950	1957	1972
Top 20 majors					
Number of plants	134	133	131	123	117
Crude capacity (thousand barrels per day)	2,711	3,365	5,262	7,207	11,273
Average capacity (thousand barrels per day)	20.1	24.3	40.1	58.6	96.4
Percent of industry capacity	72	72.7	78.6	79	84
Independents					
Number of companies	230	363	203	165	121
Number of plants	278	409	235	196	129
Crude capacity (thousand barrels per day)	1,055	1,364	1,434	1,917	2,160
Average capacity (thousand barrels per day)	3.8	3.3	6.1	9.8	16.4
Percent of industry capacity	28	28	21.4	21	16

Source: Figures for 1930-57 from De Chazeau and Kahn, p. 488. Data for 1972 from "Oil and Gas Journal," Apr. 2, 1973, pp. 99-127.

TABLE D.2.1-3. U. S. CRUDE OIL PRODUCTION, CAPACITY, AND EXCESS CAPACITY, 1954-73 [AHC-75]

Year	Crude oil production	Production capacity	Excess capacity (10 <sup>9</sup> bbls)	Excess capacity (percent)
1954	2,315	2,893	0,578	19.98
1955	2,484	3,041	.597	19.38
1956	2,617	3,259	.642	19.70
1957	2,617	3,376	.759	22.44
1958	2,449	3,463	1,015	29.32
1959	2,575	3,524	.949	26.93
1960	2,575	3,543	.968	27.32
1961	2,622	3,611	.989	27.39
1962	2,676	3,680	1,004	27.28
1963	2,753	3,712	.959	25.84
1964	2,787	3,754	.967	25.76
1965	2,849	3,845	.995	25.90
1966	3,028	3,921	.893	22.77
1967	3,216	4,033	.817	20.26
1968	3,329	4,095	.765	18.71
1969	3,372	4,020	.648	16.35
1970	3,517	3,940	.423	10.74
1971	3,453	3,740	.287	7.68
1972	3,468	3,760	.292	7.76
1973	3,367	3,550	.183	5.16

Source: 1954-68 production and capacity from American Petroleum Institute, "Petroleum Facts and Figures, 1971," pp. 101 and 110. 1969-71 production from American Petroleum Institute, "Annual Statistical Review," 1972, p. 5. 1959-71 capacity from "Oil and Gas Journal," May 15, 1972, p. 52. 1972 production from "Oil and Gas Journal," Dec. 25, 1972, pp. 82-85. 1972 capacity from "Oil and Gas Journal," June 25, 1973, p. 58. 1973 production from "Oil and Gas Journal," Dec. 31, 1973, p. 87; 1973 capacity from "Oil and Gas Journal," July 8, 1974, p. 86.

TABLE D.2.1-4. TRANSOCEANIC OIL TRANSPORTATION COSTS PER BARREL

Trip	Present Cost	1980 Estimates
Persian Gulf - N.Y. (11,800 miles)	\$ 0.104	0.064
Venezuela - N.Y. (1,800 miles)	0.212	0.148
Gulf Coast - N.Y. (2,500 miles)	0.300	0.180

TABLE D.2.1-5. EFFECT OF SHIP SIZE ON TRANSOCEANIC OIL TRANSPORTATION COSTS

Size of ship	(1000 tons)	35	100	207	250	315	372
Cost per ton	(constant \$)	135	91	78	65	67	66

oil transportation by supertankers in 1980 (middle - to long-term charter rates) is listed in Table D.2.1-4 with the present cost in (cents/ $10^6$  BTU)/(100 miles). [Hottel-71,60]

Larger tankers, however, have brought with them a series of problems:

They cannot use many harbors because of their tremendous draft.

They must bypass the Suez and Panama Canals, at least for several years to come.

The loading and unloading problem has forced the development of offshore loading facilities, designed to minimize time cost in port.

The large new ships have been automated to the greatest extent possible in order to cut the rather substantial cost of crew. The data presented in Table D.2.1-5 suggests that tanker size may settle down for a while in the 250,000 ton size.

The increased size and number of oil tankers playing the world's waterways poses new pollution problems of unprecedented nature if a 300,000 dwt tanker were to sink. The possibilities of such a disaster are increased by the fact that the tankers are underpowered and much less maneuverable than smaller ships.

It has been estimated that two million tons of crude oil are lost on the high seas during routine bilge cleaning operations by the 3748 tankers operating in the worldwide trade and all other commercial and naval vessels. This loss is roughly 0.2% of the BTU content of the crude oil and refined petroleum products used by the U. S. per year.

Internally, pipelines in the U. S., a network of 145,000 miles of crude oil lines and 64,500 miles of products lines carry more than 45% of all petroleum products transported within the U. S., totalling 680 million tons annually. The remainder is transported by railroad tank cars (6-12000 gallons each), thousands of barges (each of an average carrying capacity of 26000 barrels of oil) and by truck. In 1970 crude and products transported domestically amounted to 1.6 billion tons of petroleum. 47% was transported by pipeline, 24% by water, 28% by motor vehicles and 1.6% by rail.

According to the Federal Power Commission the average cost for moving oil through pipelines is around 1.0 cent/ $10^6$  BTU/100 miles. In a given situation this may be as high as 1.6 or as low as 0.4 cents. Two factors which play an important role in pipeline economics are economies of scale and load factor. Reduction in costs through the use of larger diameter from 10 to 24 inches can reduce unit cost of transportation by 60%.

Some areas of greater challenge in which there is potential for technical progress include detection of interfaces between product batches in pipelines to permit full automation of the line, development of successful insulation techniques to permit pipelining of heated heavy fuel oil and the development of automatic welding techniques to reduce this important component of construction costs.

Hydrocarbon losses associated with fuel handling (truck loading, underground storage, auto tank refueling) are as follows:

	<u>Percent</u>
Truck loading	0.067
From Underground tank	0.200
Auto tank refueling	0.200

It is estimated that 1910 tons of hydrocarbons are lost each day at service station refueling pumps. This represents potentially serious air and water pollution as well as loss of  $7.7 \times 10^{10}$  BTU/year.

### Market Concentration

The number and size of the sellers in a market have significant effects on the price consumers pay. As the market proceeds from one with a homogeneous product and a large number of small sellers (pure competition) to the limit of one seller (monopoly), the consumers generally bear higher prices. Tables D.2.1-6, D.2.1-7 and D.2.1-8 indicate that the petroleum industry is dominated by a few sellers (oligopoly).

Vertical Integration by a company is the control of a product flow from the resource stage to the retail stage. Tables D.2.1-6, D.2.1-7 and D.2.1-9 show the dominance of the big 7 and 20 firms in the industry. As will be seen below, the majors have dominated the international oil scene.

Horizontal Integration is a movement at a certain production stage to expand opportunities in that stage. Although not showing actual magnitudes, Table D.2.1-10 shows which alternative energy sources the majors were "buying into" in 1970. Some are closely related to petroleum itself, e.g., gas, shale and tar sands. Coal and uranium are basically substitutes. They present competition to oil as a source of energy with promise for long-term future use in the U. S. When the big oil companies diversify into these areas, they further limit the competitiveness of the overall energy industry.

Traditional conservation in petroleum consisted of controlling the rate of production from known reservoirs. Owners of land above these oil pools would lease their land to several producers. The "rule of capture" was to produce as fast as possible to get more crude than the others. There is, however, a "maximum efficiency rate" of production that provides the largest ultimate primary recovery. This makes the most use of the natural drives. Prorating slowed the rate of production by restricting it to meet the existing demand. Some fraction of this demand was assigned to each producer. Most of the oil-producing states adopted measures that restricted production.

TABLE D.2.1-6. REFINERY PLANTS AND CAPACITY,  
BY MAJOR AND INDEPENDENTS, 1930, 1940, 1950, 1957, and 1972  
[AHC-75]

	1930	1940	1950	1957	1972
<b>Top 20 majors:</b>					
Number of plants.....	134	138	131	123	117
Crude capacity (thousand barrels per day).....	2,711	3,365	5,262	7,207	11,273
Average capacity (thousand barrels per day).....	20.1	24.3	40.1	58.6	95.4
Percent of industry capacity.....	72	72.7	78.6	79	84
<b>Independents:</b>					
Number of companies.....	230	363	203	165	121
Number of plants.....	278	409	235	196	129
Crude capacity (thousand barrels per day).....	1,055	1,364	1,434	1,917	2,100
Average capacity (thousand barrels per day).....	3.6	3.3	6.1	9.8	16.4
Percent of industry capacity.....	28	28	21.4	21	16

Source: Figures for 1930-57 from De Chazeau and Kahn, p. 486. Data for 1972 from "Oil and Gas Journal," Apr. 2, 1973, pp. 99-127.

TABLE D.2.1-7. PERCENTAGES OF CRUDE OIL PRODUCTION, REFINING AND GASOLINE  
MARKETING BY THE TOP 7 AND TOP 20 COMPANIES, 1955 AND 1972 [AHC-75]

	1955		1972	
	7 companies	20 companies	7 companies	20 companies
Net crude products.....	29.1	47.5	49.0	75.2
U.S. refining throughput.....	53.7	86.4	53.7	83.5
Sales of gasoline.....	49.6	80.4	46.9	74.6

Source: Data for 1955 from M.G. De Chazeau and Alfred E. Kahn, "Integration and Competition in the Petroleum Industry," (New Haven: Yale University Press, 1959), p. 18. Data for 1972 from National Petroleum News, "Mid-May Fact Book, 1973" and "Oil and Gas Journal," Mar. 17, 1973, p. 111.

Statement of the American Petroleum Institute, presented by Frank N. Ikard, before the Subcommittee on Special Small Business Problems of the Select Committee on Small Business, U.S. House of Representatives, July 14, 1971.

TABLE D.2.1-8. TOP 20 CRUDE OIL PRODUCING FIRMS AND THEIR RANKINGS IN REFINING  
AND GASOLINE SALES, 1972 [AHC-75]

Firm	Percent of U.S. crude oil production	Percent of domestic refinery runs	Refining rank	Percent of U.S. gasoline sales	Gasoline sales rank
Exxon.....	10.6	8.8	1	6.8	4
Texaco.....	10.1	8.6	2	8.1	1
Shell.....	7.0	8.4	3	7.1	2
Gulf.....	6.2	6.6	7	6.5	5
Standard, Indiana.....	5.3	8.2	4	6.9	3
Standard, California.....	5.1	7.0	6	4.7	8
Atlantic-Richfield.....	4.8	6.1	8	4.9	7
Mobil.....	4.3	7.3	5	6.4	6
Getty.....	3.5	1.0	19	.7	23
Phillips.....	2.9	3.3	13	4.1	9
Union Oil, California.....	2.9	3.6	11	3.0	10
Sun.....	2.6	3.8	9	3.8	11
Continental.....	2.4	2.9	14	2.3	12
Cities Service.....	2.4	2.3	16	1.9	13
Marathon.....	2.0	2.0	17	1.7	14
Amerasia Hess.....	1.0	3.7	10	.7	20
Skelly.....	.4	.6	23	.6	24
Union Pacific.....	.5	1.1	18	.3	(1)
Kerr-McGee.....	.4	.3	(1)	.7	21
Standard, Ohio.....	.3	3.4	12	1.2	16

1 Too small to rank.

Source: National Petroleum News, "Mid-May Factbook, 1973."

ORIGINAL PAGE IS  
OF POOR QUALITY

TABLE D.2.1-9. U. S. CRUDE OIL PRODUCTION, CAPACITY, AND EXCESS CAPACITY, 1954-73 [AHC-75]

Year	Crude oil production	Production capacity	Excess capacity (10 <sup>9</sup> bbls)	Excess capacity (percent)
1954	2,315	2,893	0,578	19.98
1955	2,484	3,081	.597	19.38
1956	2,617	3,259	.642	19.70
1957	2,617	3,376	.759	22.48
1958	2,449	3,465	1,016	29.32
1959	2,575	3,524	.949	26.93
1960	2,575	3,543	.968	27.32
1961	2,622	3,611	.989	27.39
1962	2,676	3,680	1,004	27.28
1963	2,753	3,712	.959	25.84
1964	2,787	3,754	.967	25.76
1965	2,849	3,845	.996	25.90
1966	3,028	3,921	.893	22.77
1967	3,216	4,033	.817	20.26
1968	3,329	4,095	.766	18.71
1969	3,372	4,020	.648	16.35
1970	3,517	3,940	.423	10.74
1971	3,453	3,740	.287	7.68
1972	3,468	3,760	.292	7.76
1973	3,387	3,550	.163	5.16

Source: 1954-68 production and capacity from American Petroleum Institute, "Petroleum Facts and Figures, 1971," pp. 101 and 110. 1969-71 production from American Petroleum Institute, "Annual Statistical Review," 1972, p. 5. 1969-71 capacity from "Oil and Gas Journal," May 15, 1972, p. 52. 1972 production from "Oil and Gas Journal," Dec. 25, 1972, pp. 82-85. 1972 capacity from "Oil and Gas Journal," June 25, 1973, p. 58. 1973 production from "Oil and Gas Journal," Dec. 31, 1973, p. 87. 1973 capacity from "Oil and Gas Journal," July 8, 1974, p. 86.

TABLE D.2.1-10. DIVERSIFICATION OF PETROLEUM COMPANIES INTO RELATED ENERGY SOURCES AS OF 1970 [AHC-75]

Petroleum company	Energy industry				
	Gas	Oil shale	Coal	Uranium	Tar sands
Exxon	X	X	X	X	X
Texaco	X	X	X	X	X
Gulf	X	X	X	X	X
Mobil	X	X	X	X	X
Standard of California	X	X			
Standard of Indiana	X	X			
Shell	X	X	X	X	X
Atlantic Richfield	X	X	X	X	X
Phillips	X	X	X	X	X
Continental	X	X	X	X	X
Sun Oil	X	X	X	X	X
Union Oil of California	X	X	X	X	X
Occidental	X	X	X	X	X
Cities Service	X	X	X	X	X
Betty	X	X	X	X	X
Standard of Ohio	X	X	X	X	X
Pennzoil United, Inc.	X	X	X	X	X
Signal	X	X	X	X	X
Marathon	X	X	X	X	X
Amstar-Hess	X	X	X	X	X
Ashland	X	X	X	X	X
Kerr-McGee	X	X	X	X	X
Superior	X	X	X	X	X

1 Includes Hooker Chemical Co.

2 Includes Skelly and Tidewater.

3 Includes reported British Petroleum assets.

4 As of June 30, 1969.

5 As of Sept. 30, 1969.

Source: Federal Trade Commission, "Market Boundaries in the Energy Sector of the U.S. Economy," Committee on Interior and Insular Affairs, U.S. Senate, Aug. 8, 1972, p. 798.

ORIGINAL PAGE IS  
OF POOR QUALITY

Governmental intervention has taken forms other than those already mentioned. Among the most famous are the depletion allowance (27% of the resource value was deducted from taxable income each year of the producing life of the well, even if more than 100% was eventually deducted), tax incentives and price controls. The oil depletion allowance was cancelled.

Foreign oil has become an increasingly important portion of U. S. oil consumption (Table D.2-4). The Arab oil embargo awakened the nation to its growing vulnerability to foreign discretion. Although foreign oil has been flowing into the U. S. for several decades, it has not presented a problem until fairly recently. This has not only been due to the approaching of the limit of domestic reserves. The shift of power in the world petroleum market has had important consequences. In 1950, the seven big international oil companies (See note 1 under Table D.2.1-11 and leave out Compagnie Francaise) dominated the scene. The host countries were given relatively small payments for their oil. The big 7 had the technology, size and vertical integration (cartel power) to minimize the effects of independent companies. As the foreign producing countries became more sophisticated in bargaining procedures, they began to use independents to get higher payments from the company cartel. Higher royalties and taxes and more ownership paved the way for the formation of OPEC in 1960. OPEC is now the dominant force in the world petroleum market, although ventures like ARAMCO show that some company and country interests are the same. Table D.2.1-11 gives the % production of the OPEC countries by the major companies for years between 1965 and 1972. Table D.2.1-12 shows U. S. imports by country of source from 1950-73.

The relation of recent world prices to domestic prices is depicted for 1971 and 1974 in Table D.2.1-13. The price elasticity of demand (the ratio of a % change in quantity purchased of a good to a % change in price) for oil products is estimated to be between .2 and .4. Price elasticity of supply (replace "quantity purchased" with "quantity supplied" above) is thought to be about 1. This implies that as prices rise, supplies will increase proportionally more than demands decrease. People and firms end up spending more in total for slightly less consumption. This is a high-cost way of achieving a small demand reduction. Supplies will continue to increase until it is no longer economically possible or there are no reserves left in the country.

Some others believe in a threshold of demand inelasticity. If the prices of oil products get high enough, people will decrease consumption (by curtailment and/or substitution) in a vigorous way. The income effects of the current recession also lead to curtailed use. If high prices lead to substantial increases in discovery, recovery and new technologies, a high supply will meet a low demand. The popular phrase for the result of such phenomena is that the world would be "knee deep" in oil. The power of the OPEC cartel to withstand such pressures is uncertain at this time. If they cannot restrict supply to a large degree, then prices will tumble. This may again speed up the approach to the earth's finite oil reserve limit. Lower prices may have stifling effects on budding but expensive technologies.

TABLE D.2.1-11. PRODUCTION OF OPEC COUNTRIES BY THE MAJOR INTERNATIONAL COMPANIES,<sup>1</sup> 1965, 1969-72 [AHC-75]

[In percent of total]

OPEC countries	1965	1969	1970	1971	1972
Abu Dhabi <sup>2</sup>	96.2	96.9	97.0	95.9	97.2
Algeria <sup>3</sup>	33.2	8.9	3.1	0	0
Indonesia	88.4	85.2	86.6	86.9	79.9
Iran	91.2	82.0	82.5	80.9	85.8
Iraq <sup>4</sup>	95.1	95.0	95.0	95.0	64.7
Kuwait	100.0	100.0	100.0	100.0	100.0
Libya <sup>4</sup>	50.8	58.1	47.9	47.1	41.4
Nigeria	100.0	100.0	99.6	95.5	93.6
Qatar	94.4	97.1	97.6	97.5	97.2
Saudi Arabia	100.0	100.0	100.0	100.0	100.0
Venezuela	87.8	85.9	83.1	86.5	87.2
Major share, weighted average of Middle Eastern countries	96.8	93.8	93.9	93.7	92.4
Total major share of OPEC production	87.9	83.7	83.1	84.4	83.4

<sup>1</sup> British Petroleum, Compagnie Francaise des Petroles, Exxon, Gulf, Mobil, Royal Dutch/Shell, Socal, and Texaco.<sup>2</sup> Later the dominant element of the United Arab Emirates.<sup>3</sup> Petroleum production nationalized during this period.<sup>4</sup> Petroleum production partially nationalized during this period.

Source: "Petroleum Times," various dates.

TABLE D.2.1-12. IMPORTS OF CRUDE OIL BY ORIGIN, 1950-73 [AHC-75]

[Millions of barrels]

Year	Arab countries	Iran	Venezuela	Canada	Nigeria	Indonesia <sup>1</sup>	Other	Total
1950	40.3	0	107.7	0	0	0	25.9	173.9
1951	37.8	0	105.8	.5	0	0	33.4	177.5
1952	57.2	0	119.3	1.1	0	3.6	26.3	207.5
1953	80.4	0	116.1	2.6	0	14.4	19.7	233.2
1954	77.1	.2	129.7	2.6	0	13.8	19.2	242.6
1955	98.3	3.1	148.8	16.4	0	11.8	13.0	291.4
1956	96.3	7.2	167.0	42.7	0	13.3	15.2	341.8
1957	81.2	6.6	193.8	55.1	0	23.7	12.8	373.2
1958	117.7	5.3	158.2	30.4	0	21.1	15.3	348.0
1959	115.9	9.0	165.9	33.7	0	20.0	17.0	352.3
1960	114.6	13.1	172.9	41.3	0	26.7	16.0	371.6
1961	120.9	22.0	155.8	66.6	0	22.7	15.6	381.5
1962	118.4	17.7	169.0	95.1	0	24.5	13.5	411.0
1963	112.4	22.7	174.5	90.4	0	21.3	14.0	412.7
1964	126.6	24.1	174.2	101.6	0	23.0	13.2	438.6
1965	141.2	28.6	157.8	107.8	5.3	22.2	17.8	452.0
1966	135.0	30.8	147.4	126.7	4.1	18.2	19.7	447.1
1967	136.0	23.8	131.1	150.4	1.4	22.5	20.1	411.6
1968	126.7	21.2	125.7	164.4	3.1	26.6	20.8	472.3
1969	125.6	15.3	111.7	203.3	17.9	32.3	23.2	514.1
1970	114.4	12.2	98.0	245.3	17.5	25.7	8.1	483.3
1971	135.2	38.6	110.6	263.3	34.8	40.2	9.3	613.4
1972	230.9	49.7	93.3	312.4	88.9	59.6	26.0	811.1
1973 <sup>1</sup>	211.0	69.7	116.1	364.3	168.3	73.4	169.6	1172.4

<sup>1</sup> Preliminary. Data for Indonesia include all of "Far East."

Source: 1950-55 data from U.S. Department of Interior, "Minerals Yearbook," 1951, 1955, 1955. 1956-72 data from American Petroleum Institute, "Annual Statistical Review," 1973, pp. 9-10. 1973 data from "Oil and Gas Journal," Jan. 28, 1974, p. 113.

ORIGINAL PAGE IS  
OF POOR QUALITY



TABLE D.2.1-13. PETROLEUM INDUSTRY DATA SUMMARY, JANUARY, 1971, and JANUARY, 1974 [AHC-75]

	1971	1974
Landed price of imported crude oil (dollars per barrel).....	2.945	12.81
Production cost.....	.12	.10
Royalty.....	.224	1.456
Tax.....	.759	5.552
Transportation cost.....	1.40	1.875
Import duty.....	.105	.105
Company margin.....	.337	3.722
Domestic crude oil price (average dollar/barrel).....	3.41	6.44
Old oil (controlled).....		5.25
New oil (uncontrolled).....		10.00
Refined products, Wholesale Price Index (1967 = 100).....	107.9	166.4
Petroleum product prices		
Gasoline, regular (cents per gallon).....	35.56	45.28
Dealer tank wagon price.....	17.56	26.23
Production cost.....	11.5	NA
Transportation cost.....	1.0	NA
Distribution cost.....	5.06	NA
Dealer margin.....	7.0	8.0
Tax.....	11.0	11.0
Home heating oil (No 2, cents per gallon).....	18.09	36.4
Production cost and refinery margin.....	9.88	NA
Transport cost.....	.88	NA
Dealer margin and distribution cost.....	6.43	NA
Tax.....	.9	.9
Performance (27 largest firms):		
Net profits (millions of dollars).....	6,319	<sup>1</sup> 14,028
Net liquids production (million barrels).....	7,828	<sup>2</sup> 8,890
Refined product sales (million barrels).....	8,441	<sup>2</sup> 9,204
Net profit/product sales (dollars per barrel).....	0.75	<sup>3</sup> 1.52
Refinery runs (million barrels).....	7,568	<sup>2</sup> 8,381
Production/refinery runs.....	1.03	<sup>2</sup> 1.06

<sup>1</sup> Annual rate based on 1st quarter 1974 profits of \$3,506,924<sup>2</sup> 1973 figures.<sup>3</sup> 1974 profit rate divided by 1973 product sales

## Natural Gas

Production of natural gas for the most part has been associated with the production of oil. As its advantages (highly efficient and available in an energy sense, clean) became known, it was sought separately from oil. Table D.2.1-1 shows that production increased with small exception during 1950-73 while reserves peaked in 1970 (Alaska added).

The transportation of natural gas through interstate pipeline is quite efficient. It is estimated that about 332 billion cubic feet of gas are lost out of 21 trillion cubic feet pumped through the system. It is interesting to note that about 1/10% of the energy transported per year is required to pump this gas.

The cost of long-distance transmission of gas varies between one to three cents per million BTU per 100 miles. Costs are relatively insensitive to distances beyond the 80 or 100 miles that compose a line section, but economies of scale are very significant. Pipelines installation costs are sensitive to the remoteness and roughness of the terrain, as indicated by the estimate of 3 cents/10<sup>6</sup> BTU/100 miles for 48" trans-Alaska pipeline and 1.35 cents estimate for a line from Portland, Oregon to Los Angeles.

The chief prospect for reduction in transportation cost lies in the capital savings associated with development of lighter and stronger pipe and improved construction techniques.

At the end of 1969, there were 320 large underground storage reservoirs with a capacity of 4.9 trillion cubic feet. It is estimated currently that 2.3% of the natural gas produced for transmission and distribution is wasted. Most of this loss, probably, is in the distribution where in many cities the piping system dates from the 19th century.

## Liquefied Natural Gas (LNG)

LNG, in the U. S., is used primarily for peak shaving and in situations in which normal gas transmission and distribution is either unavailable or uneconomical. The technology for shipping LNG by truck is well in hand, having been developed for commercial liquefied gases and for handling liquid gases in the aerospace program. Much more economical for long distance shipment are cryogenic railroad cars. Use of pipelines has been considered and rejected for long distance shipment; insulation and refrigeration stations needed on long distance LNG pipelines is undecided, one published figure is every 25 miles, while another report recommends every 100 to 150 miles.

The design of LNG tankers has been developing rapidly since the first prototype went to sea in 1959. An attempt has been made recently to improve tanker hull space utilization and reduce costs through introduction of the membrane concept. In a membrane tanker, self supporting tanks for the LNG are replaced by a thin membrane of cryogenic material which is supported by the insulation and hull and is molded to closely follow hull contours.

About 7 billion cubic feet of natural gas is liquefied annually in the U. S. and stored in the liquid form. The handling and evaporation of LNG will become very important in the future when as much as one trillion cubic feet is expected to be imported per year.

Government intervention, aside from that connected with oil production (gas providing an important natural drive in crude oil wells), has mainly involved the control of prices in interstate sales of gas. It is generally felt that gas prices were kept artificially low. This encouraged overuse of gas as well as lower demands (and hence lower prices) of other energy resources.

Environmental effects of gas industry operations are strongly related to oil drilling operations. Other factors are leaks or spills. As a fuel, natural gas is very clean, i.e., there are no serious air pollution problems.

### Coal

Coal reserves in the United States are truly staggering. Resources known from exploration and mapping are 1581 billion tons as shown in Table D.2.1-14. This includes all anthracite and bituminous coal in seams greater than 14 inches and all subbituminous coal and lignite in seams greater than 30 inches to a depth of 3000 ft. An equal amount of coal is projected in unmapped regions and to a depth of 6000 ft. Altogether this gives an anticipated resource of around 3200 billion tons.

Under present mining techniques only about 1/3 of the known reserves can be extracted; with improved technology it is anticipated that around 1/2 of these reserves may be utilized. Using the most recent statistics from 1971 the rate of production was only 0.552 billion tons so that reserves are ample for the foreseeable future.

Not only are coal reserves extensive, they are also widely distributed across the continental United States, occurring broadly in each section except the extreme western states. This distribution is illustrated in Figure D.2.1-1 and again in Table D.2.1-15. Coal is generally classified by type and sulfur content. Bituminous coals generally have a thermal content of between 12000 to 15000 BTU/lb.; subbituminous coals are between 8000 and 11000 BTU/lb. and lignite, between 7000 to 8000 BTU/lb. Eastern coals are generally of the higher thermal content type and offer an advantage in shipping costs. Western coals are frequently found near the surface and are in thicker seams so that mining costs are generally less. Perhaps even more important is the lower average sulfur content of western coals.

The most significant trends in mining over the past 30 years include increased mechanization and a movement toward strip mining. In 1947, .491 billion tons were from underground mines whereas only .139 billion tons were from surface mines. Average productivity for underground mines was 5.49 tons/man-day and for surface mines was 15.93 tons/man-days. By 1969 underground mines production had dropped to .3635 billion tons and surface mining increased to .197 billion tons. Average productivity

TABLE D.2.1-14. TOTAL ESTIMATED COAL RESERVES OF THE  
UNITED STATES, JANUARY 1, 1972, BY STATES  
WITH MORE THAN 10 BILLION SHORT TONS  
[D. A. Probst and W. P. Pratt-73]

<u>State</u>	<u>Identified Reserves</u>	<u>Hypothetical Reserves Overburden</u>		<u>Total Reserves</u>
		<u>0-3000 ft</u>	<u>3000-6000 ft</u>	
		In Millions of Short Tons		
Alabama	15,342	20,000	6,000	41,342
Alaska	130,081	130,000	5,000	265,081
Arizona	21,246	0	0	21,246
Colorado	80,581	146,000	145,000	371,581
Illinois	139,124	100,000	0	239,124
Indiana	34,573	22,000	0	56,573
Iowa	6,509	14,000	0	20,509
Kansas	18,674	4,000	0	22,674
Kentucky	64,842	52,000	0	116,842
Missouri	31,014	18,200	0	49,214
Montana	221,675	157,000	0	378,675
New Mexico	61,427	27,000	21,000	109,427
North Dakota	350,630	180,000	0	530,630
Ohio	41,358	2,000	0	43,358
Oklahoma	3,281	20,000	10,000	33,281
Pennsylvania	77,269	10,000	0	87,269
Texas	12,872	14,000	0	26,872
Utah	23,721	21,000	35,000	79,721
Virginia	9,687	5,000	100	14,787
Washington	6,179	30,000	15,000	51,179
West Virginia	100,628	0	0	100,628
Wyoming	120,656	325,000	100,000	545,656
<u>Other States</u>	9,618	9,080	5	18,703
<u>United States</u>	1,580,987	1,306,280	337,105	3,224,372

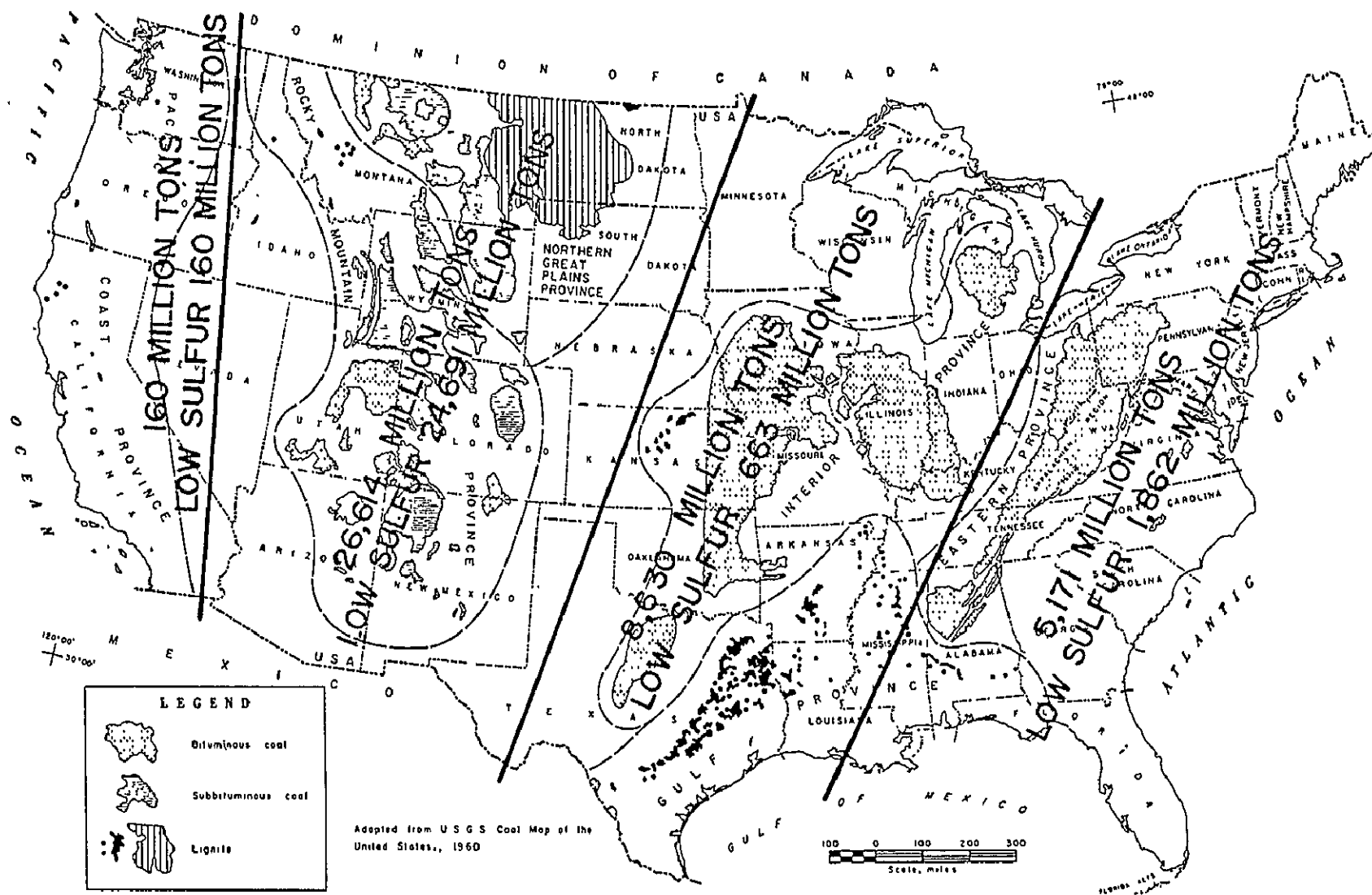


FIGURE D.2.1-1. STRIPPABLE RESERVES OF THE CONTIGUOUS UNITED STATES, BY REGION

TABLE D.2.1-15. IDENTIFIED COAL RESERVES OF THE UNITED STATES,  
JANUARY 1, 1972, BY STATES WITH MORE  
THAN 10 BILLION SHORT TONS  
[U. S. Geological Survey-74]

<u>State</u>	<u>Bituminous Coal</u>	<u>Sub-Bituminous Coal</u>	<u>Lignite</u>	<u>Total</u>
<u>In Millions of Short Tons</u>				
<u>Eastern Province</u>				
Alabama	13,342		2,000	15,342
Kentucky	64,842			64,842
Ohio	41,358			41,358
Pennsylvania	56,759 (and 20,510 Anthracite)			77,269
West Virginia	100,628			100,628
	<u>297,439</u>			<u>299,439</u>
<u>Interior Province</u>				
Illinois	139,124			139,124
Indiana	34,573			34,573
Kansas	18,674			18,674
Missouri	31,014			31,014
Texas	6,048		6,824	12,872
	<u>229,433</u>			<u>236,257</u>
<u>Northern Great Plains Province</u>				
Montana	2,299	131,855	87,521	221,675
N. Dakota			<u>350,630</u>	<u>350,630</u>
			438,151	572,305
<u>Rocky Mountain Province</u>				
Arizona	21,246			21,246
Colorado	62,339	18,242		80,581
New Mexico	10,752	50,671		61,423
Utah	23,541	180		23,721
Wyoming	12,705	107,951		120,656
	<u>130,583</u>	<u>177,044</u>		<u>307,627</u>
<u>Other States</u>	47,641	115,174	2,544	165,359
<u>U.S. Total</u>	<u>707,395</u>	<u>424,073</u>	<u>449,519</u>	<u>1,580,987</u>

increased to 15.6 tons/man-day in underground mines primarily due to introduction of continuous mining techniques. Productivity in surface mines had increased to 35.7 tons/man-day. [Papamarcos-74,39]

Currently enough new mines are being opened to produce .237 billion tons of new production. Surface mines account for about 60% of this new capacity as seen in Table D.2.1-16. Development is almost evenly divided between mines east and west of the Mississippi as shown in Table D.2.1-17. This indicates the need to develop mines in regions where low sulfur coal is abundant.

Coal is transported by a number of carrier conveyances. The principal carriers used for coal transportation are: railroad, truck, water borne carrier and pipeline.

In practice, the employed transportation conveyance is determined on the basis of economies. The endeavor to maximize economic gains is instrumental in selecting a given transportation mode for particular source/destination/volume parameters.

In 1967:

553,600 x 10<sup>3</sup> tons were moved by rail,  
 198,789 x 10<sup>3</sup> tons were moved by river,  
 106,156 x 10<sup>3</sup> tons were moved on Great Lakes,  
 46,736 x 10<sup>3</sup> tons were moved by tidewater,  
 45,194 x 10<sup>3</sup> tons were moved by truck,  
 32,812 x 10<sup>3</sup> tons were moved by tramway, conveyor and private  
 railroads.

In general, 3.3% of the coal is used at the mine, 11.5% is moved by water, 12.6% by motor vehicle and 72.5% by rail.

The most advanced railroad hauling technology now in regular use is the unit trains concept, which consists of conventional equipment operating continuously in a train dedicated to the service of one customer. This concept can increase the utilization of cars by as much as 600% and reduces the cost of loading, unloading and switching associated with coal shipment as part of a general train carrying many different types of goods.

Another step in reducing costs is the construction of trains specifically designed for shuttle use, dubbed integral trains. Such trains would consist of extra large cars semipermanently coupled with power units interspersed among the cars, and especially designed for rapid loading and unloading. With power units at either end, the trains would not need to be turned around at terminals. For this train to be economical, it would

TABLE D.2.1-16. NEW COAL MINE CAPACITY TOTALS BY YEARS BY MINING METHOD AND NUMBER OF MINES (THOUSANDS OF TONS) [Nielsen-75, 130]

Year	Deep Cap.	No. of Mines	Strip Cap.	No. of Mines	Auger Cap.	No. of Mines	Total Cap.	Total Mines
1973	4,120	8	9,600	7	200	2	13,920	17
1974	15,948	15	7,130	12	--	--	23,078	27
1975	10,688	17	4,535	4	--	--	15,223	21
1976	13,327	13	11,800	4	--	--	25,127	17
1977	21,370	16	2,800	1	--	--	24,170	17
1978	11,040	10	2,500	1	--	--	13,540	11
1979	9,064	5	20,500	2	--	--	29,564	7
1980	4,000	1	34,000	4	--	--	38,000	5
1981	5,000	2	---	--	--	--	5,000	2
1982	---	--	14,000	1	--	--	14,000	1
1983	---	--	35,000	2	--	--	35,000	2
Total	94,567	87	141,865	38	200	2	236,622	127



TABLE D.2.1-17. NEW COAL MINE CAPACITY TOTALS BY  
MINING METHOD AND NUMBER OF MINES  
(THOUSANDS OF TONS) [Nielsen-75, 130]

State	Deep Cap.	No. of Mines	Strip Cap.	No. of Mines	Auger Cap.	No. of Mines	Total Cap.	Total Mines
Ala.	11,750	6	-	-	-	-	11,750	6
Ariz.	-	-	8,000	1	-	-	8,000	1
Ill.	18,900	7	8,300	3	-	-	27,200	10
Ind.	4,000	1	6,000	2	-	-	10,000	3
Kans.	-	-	500	1	-	-	500	1
Ky.	7,370	11	6,850	7	200	2	14,420	20
Md.	-	-	120	1	-	-	120	1
Mont.	-	-	21,000	2	-	-	21,000	2
N.M.	-	-	5,000	2	-	-	5,000	2
Ohio	7,400	4	950	2	-	-	8,350	6
Pa.	9,388	10	1,260	3	-	-	10,698	13
Tenn.	-	-	100	1	-	-	100	1
Tex.	100	1	-	-	-	-	100	1
Utah	1,300	2	-	-	-	-	1,300	2
Va.	1,200	1	-	-	-	-	1,200	1
Wash.	-	-	1,000	1	-	-	1,000	1
W.Va.	32,149	43	1,285	4	-	-	33,434	47
Wyo.	1,000	1	81,500	8	-	-	82,500	9
Total	94,557	87	141,865	38	200	2	236,622	127

have a capacity of about 35,000 tons compared with 10,000 tons or so for current large trains. Studies indicate that the integral train should be competitive with coal pipelines and even gas pipelines. It should be remembered that railroads' flexibility and hence ability to institute new procedures is hindered by rate regulation, labor problems, uncertainty caused by mergers, etc.

On the other hand, the only commercial slurry pipeline which has been operated in the U. S. prior to the line from Black Mesa to the Mohave was built in Ohio. It began services in 1958 and contrived to run through 1963. The operation of the Ohio pipeline is generally thought to have proved coal transportation by pipeline to be workable and slurry preparation to be feasible, but it did not prove out any method for slurry utilization which was deemed satisfactory.

It has been suggested that oil rather than water be used for slurring, to increase the energy throughout of coal slurry pipelines. While this might be attractive if coal and oil were found together and shipped to the same destination, the costs of moving oil to the coal field makes this economically unattractive. In addition, oil slurry is more difficult to handle.

## D.2.2 THE ELECTRICITY INDUSTRY

Historical production of electric power from 1947-74 is given in Table D.2.2-1. Over this period there has been a relatively high rate of growth in electrical usage. An especially pressing problem in the production of electricity is the need to meet daily and seasonal peak demands. The daily peaks virtually bracket the eight hour work period. The seasonal peaks have varied from winter (heating and more evening lighting) to summer (air conditioning). Power companies must keep the necessary capital equipment to meet these peak demands.

### D.2.2.1 TYPES OF FUEL

Projections of growth in the electrical industry by fuel sectors is shown in Table D.2.2-2. Traditionally coal has been the major fuel source for power generation. In more recent years environmental considerations have tended to push utilities toward oil. There has also been a definite move toward nuclear power although this trend has been much slower than generally anticipated and growth targets of the nuclear industry are regularly revised downward.

### D.2.2.2 TYPES OF CONVERSION SYSTEMS

#### Oil and Coal Fired

In spite of rapid growth in the startup of nuclear plants over the past several years, fossil fuels remain dominant in the generation of

TABLE D.2.2-1 ELECTRIC POWER AND GAS -- ELECTRIC POWER

YEAR	PRODUCTION									SALES TO ULTIMATE CUSTOMERS		
	Total	Electric utilities					Industrial establishments			Total	Commercial and industrial	
		Total	By source		By type of producer		Total	By source			Small light and power	Large light and power
			Fuels	Water-power	Privately and municipally owned utilities	Other producers (publicly owned)		Fuels	Water-power			
Millions of kilowatt hours												
1947	307 400	255,739	177 313	78 425	220,521	35 218	51,661	47,021	4 641	217 581	38,379	113 52
1948	336 800	282,698	200,228	82 470	241 353	41 345	54 110	49,589	4,522	240,740	43 193	124 088
1949	345 066	291,100	201,351	89,748	246 522	44 577	53 967	48,942	5,025	246,542	46,262	120,76
1950	388 674	329,141	233,203	95 938	282 104	47 037	59 533	54 587	4,946	280 539	51 753	142,040
1951	433,358	370 673	270 922	99,751	319,462	51 211	62 685	58 060	4,626	316,168	58,770	161,233
1952	463 055	399,724	294 121	105,102	339 616	59 608	63,931	59,225	4 606	342,624	63,561	170,606
1953	514 169	442 665	337,431	105,233	375,896	66,768	71 505	67,121	4,384	384,244	70,863	193,705
1954	544 645	471,686	364 618	107 069	394 475	77,211	72,959	68 387	4,571	410,904	75,108	203,919
1955	629 010	547 038	434,083	112,975	446,721	100,317	81,972	78,711	3 261	480,921	77 880	257 937
1956	684 804	600 668	478 639	122,029	487,020	113,647	84,136	80 928	3 208	530 128	84 521	265,760
1957	716 356	631,507	501 275	130,232	509,793	122 714	84,819	81 723	3,125	557 829	91,702	291 914
1958	724 752	645,098	504,836	140,262	518,731	126 367	79,654	76 301	3,352	569 161	97 683	283,847
1959	795,251	710 006	572 224	137,781	578 852	131,154	85 245	81 872	3,373	626 743	109 079	312,618
1960	841,616	753,350	607 834	145,516	615,524	137 826	88 266	84 659	3 607	683,199	114 806	344 799
1961	878 711	792 039	640 189	151,850	643 635	148 403	86 673	83,308	3 365	720,728	134 804	347 427
1962	943 482	852,314	684 032	168,283	692,704	159,611	91 188	87 759	3,409	776 088	144 095	373 916
1963	1 008,081	914,119	748,713	165 406	745,145	168,971	93 951	90 806	3 155	830 811	166 516	388,398
1964	1 083 741	983 990	806,917	177,073	806,446	177 544	99 751	96 523	3 228	890 356	183 539	409 356
1965	1 157 583	1 055 252	861,401	193 851	859 414	195 838	102 331	99,198	3 134	953,414	202 112	433 365
1966	1 249,444	1,144 350	949,594	194,756	933,464	210,886	105 094	101,912	3 182	1,038 982	225 878	465 077
1967	1 317 301	1 214 365	992 847	221,518	986 227	228 139	102 935	99,505	3,430	1,107 023	242 492	486,043
1968	1 436 029	1,329 443	1,106 952	222 491	1 083,117	246,326	106,586	103 203	3 383	1 202 321	265,051	518 834
1969	1 552,757	1,442,182	1 191,990	250,193	1,171,776	270,406	110,575	107 799	3 276	1 307,178	286 686	557 220
1970	1 639 771	1 531 609	1 234 153	247,456	1,254 583	277,026	108,162	104 919	3,243	1 391 359	312,750	572 522
1971	1 717 520	1 613 936	1,347 616	265,320	1,322,540	291 396	103 585	100 325	3,260	1 466 441	333,752	592 699
1972	1 853,390	1,747,323	1,474 589	272,734	1 435 599	301,724	106 067	102,678	3,389	1,577 714	361,859	639 467
1973	1,947,079											
1974	1,941,095											

ORIGINAL PAGE IS  
OF POOR QUALITY

TABLE D.2.2-2.  
INSTALLED CAPACITY AND GENERATION FOR  
CENTRAL STATION POWER PLANTS<sup>a</sup>

<u>Year</u>	<u>Type of Plant</u>	<u>Installed Capacity (10<sup>3</sup> MWe)</u>	<u>Power Generated (10<sup>9</sup> kW-hr)</u>
1969	Hydropower	53	246
	Gas turbine and I-C	14	15
	Gas-Steam	78	368
	Oil-Steam	40	150
	Coal-Steam	143	761
	LWR	4	13
	Total	332	1553
1977	Hydropower	53	246
	Gas turbine and I-C	36	25
	Gas-Steam	81	392
	Oil-Steam	61	293
	Coal-Steam	203	980
	LWR	90	514
	Total	524	2450
1985	Hydropower	55	257
	Gas turbine and I-C	57	40
	Gas-Steam	79	367
	Oil-Steam	78	364
	Coal-Steam	250	1175
	LWR	258	1469
	Total	777	3672

<sup>a</sup>Includes industrial self-generation.

electrical power. At the end of 1974, installed generating capacity of electric utilities was 71% fossil fueled steam units. Moreover, another 8.2% of generating capacity was in combustion turbines and 1.1% in internal combustion engines so that altogether 80.2% of the installed capacity is fossil fueled. In comparison, 11.5% of generating capacity was in hydroelectric plants and only 6.4% in nuclear. [EW-75,58]

The breakdown by fuel sources for electrical power generation from fossil fuels is shown in Figure D.2.2-1. Historically, the bulk of electrical power generation is from coal. However, during the late 1960's use of coal leveled off in reaction to pressures from several quarters. The Coal Mine Health and Safety Act took effect in 1970. Environmental pressures and shortages of low sulfur coal also restricted coal usage. A number of plants were converted to oil and natural gas during this period. However, shortages of natural gas caused a leveling of usage after 1970, and the conversion shifted largely to oil. In 1974, a down turn is noted in the consumption of all fossil fuels for electrical power generation as economic conditions resulted in a decline in electrical power generated by fossil fuels from  $1585.7 \times 10^9$  to  $1550.4 \times 10^9$  KW-hr. The decline in coal usage can probably be attributed to cutbacks caused by strike created shortages. Reduced oil and gas usage reflects not only economic conditions but also increased fuel costs and conservation measures.

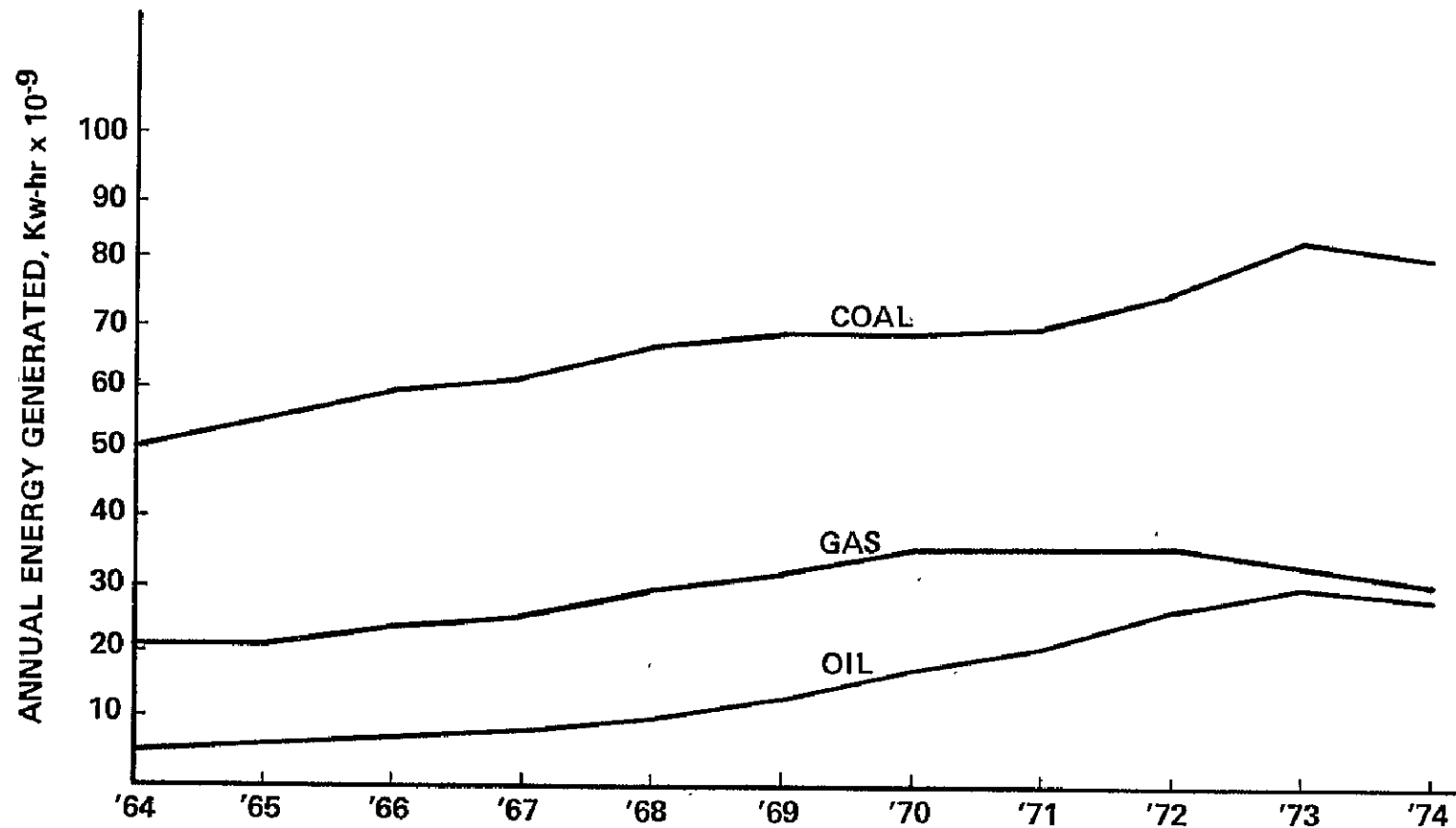
Conversion of existing oil or gas fired units to coal has been ordered by the FPC wherever possible. Generally those units originally designed for oil or gas are not economically convertible: reasons include lack of facilities to handle coal ash, differences in boiler design, lack of suitable rail access, etc. In some cases, it will be impossible to reconvert units originally designed for coal and converted to gas or oil. Upon initial conversion, several utilities sold coal storage areas or rail right-of-way so that these facilities are no longer available. Shortages of low sulfur coal may also limit reconversion. [Young -75].

Various economic pressures together with shortages of natural gas has already produced a shift back toward coal as the dominant fuel for future electrical power generation as shown below. [EW-75, 58]

#### Coal Utilization in New Orders for Fossil Fueled Generation

1971	40%
1972	60%
1973	90%
1974	98%

However, the impact of the swing to coal is impeded by the worsening financial problems affecting both the overall economy and the electric utilities. During 1974, some 100 fossil fired units involving 57,535 MW



## ELECTRICAL POWER GENERATION BY FOSSIL FUELS

FIGURE D.2.2-1

of capacity have been postponed or cancelled. This represents approximately 58% of the industrial backlog. The nuclear power industry has been similarly hard hit with 121 units totaling 126,386 MW cancelled or postponed. Another 14 nuclear units which were planned have been postponed giving 65% of the backlog which is to be delayed.

### Nuclear

By far, the largest fraction of electrical energy produced in the United States today is produced in central power stations employing steam-driven turbines to turn electric generators. All such plants have certain features in common. First, each has what is known in the industry as a "steam supply system", which produces high pressure steam from ordinary water. In today's power plants using conventional boilers, the heat needed to produce the steam is supplied by burning fossil fuels. In nuclear plants, this heat is provided by nuclear fission of uranium or other fissile material.

The nuclear energy industry in the United States is structured on three types of reactor concepts; the Pressurized Water Reactor (PWR), the Boiling Water Reactor (BWR) and the High Temperature Gas-Cooled Reactor (HTGR). As of May 1975, there were 53 nuclear power plants licensed for commercial operation: 29 PWR's, 23 BWR's and one HTGR. This corresponds to a total net maximum capacity of 36.7 GWe.

Historically, the plant load factor has been around 60 percent, including both scheduled and forced shutdowns. At the present time, three BWR's have been derated to 50% of their full power due to vibration problems associated with the incore instrumentation. Three other plants are down for repair and modifications in the Emergency Core Cooling System, and two are shut down due to a fire incident during leak testing in the control room. [NI-75,24]

The efficiency rating for a 1 GWe nuclear power plant is around 33 percent. This has varied from 19.8 to 35.9 percent for commercially licensed plants. [AEC-73-2]

The most important fuel materials presently found in the nuclear energy industry contain the isotopes of uranium (U-238, U-235 and U-233), the fissile isotopes of plutonium (Pu-239 and Pu-241), and thorium-232. Plutonium-239, not naturally available, and uranium-233 are produced from neutron capture reactions in uranium-238 and thorium-232, respectively.

Uranium in the form of uranium dioxide (about 97% U-238 and 3% U-235) fuels Light Water Reactors (LWR). In the case of the High Temperature Gas-Cooled Reactor, a combination of highly enriched uranium (over 90% U-235) and thorium-232 carbide coated particles is used as fuel. No fuel materials are commercially fabricated from plutonium and uranium-233 at the present time. They are the potential fuels for the breeder reactors envisioned in the future.

The nuclear fuel cycle typically consists of the following operations: mining and milling, conversion, enrichment, fabrication, utilization in a nuclear reactor, reprocessing, and waste management. Transportation is the common element between the various steps in the fuel cycle.

Uranium ore is obtained either from underground or open-pit mines with approximately 55% currently coming from underground mines. There are some 170 domestic uranium mines with a capacity to produce about 9 million tons of ore a year. Less than 7 million tons annually are now produced. [NI-75,31]

Conventional uranium resources, 98% from sandstone deposits, are estimated as 700,000 tons of  $U_3O_8$  (up to \$30/lb) in the category of reasonably assured resources and 1.5 million tons of  $U_3O_8$  (about \$30/lb or less) in the estimated additional resources category. The Energy Research and Development Administration (ERDA) has added another million tons of  $U_3O_8$  to the latter. [NN-75,36]

Nonconventional uranium resources are estimated at 2.7 million tons of  $U_3O_8$  at a forward cost of up to \$100 per pound of  $U_3O_8$ . These resources come mainly as by-product of the copper and phosphate industries. About 320 million pounds of uranium would be recoverable at an approximate cost of \$10 per pound from the processing phosphate solutions. Another potential source of uranium is the phosphate rock from central Florida. Actual phosphoric acid production from this rock is 4.5 million tons per year with an  $U_3O_8$  content of 4 million pounds. [NN-75,36]

Sixteen uranium milling plants are operating in the United States with a maximum capacity of 14,000 tons of uranium per year. [Poole-75,97]

Capacity for  $U_3O_8$  conversion to  $UF_6$  stands at 17,200 metric tons of uranium per annum.

The enrichment of uranium continues to be the only major step in the nuclear fuel cycle that is not performed by industry as a commercial enterprise. Uranium Enrichment Associates has a firm commitment with ERDA to build a nine million Separative Work Units (SWU) gaseous diffusion plant near Dothan, Alabama. The proposed facility will require 2,500 MWe. The plant will supply enriched uranium to approximately 100 (1GWe) nuclear power plants.

A gas centrifuge enrichment plant proposal has been submitted by CENTAR Associates to ERDA. The plant would fuel up to 30 LWR's at full commercial size in 1986. The centrifuge system requires about 10 percent of the power needed in the gas diffusion process. CENTAR points out that the plant can be operated economically at one-third the size and one-third the capital needed for a gaseous diffusion plant. [NI-75,14]

Domestic capacity for fuel element fabrication using  $UO_2$  is about 4,500 metric tons per year of uranium.



The function of the fuel reprocessing plant is to recover the residual fuel materials for re-use and isolate radioactive wastes for storage and ultimate disposal.

At the present time there are no commercial reprocessing plants in operation. This has created a backlog of LWR spent fuel elements of over 1000 metric tons of uranium. The Nuclear Fuel Services facility, shut down for expansion, plans to reopen with a capacity of 750 tons/year in 1978; the Mid-West Fuel Recovery Plant was delayed for about two years due to certain problems during the testing phase; and the Barnwell Nuclear Fuel Plant is scheduled to begin operation in late 1976, with a capacity of 1500 tons/year. Due to this situation, it is expected that the backlog of unprocessed spent fuel will extend into the near mid term (1985). [NI-75,38]

The capacity to handle the transportation of fresh fuel, spent fuel and nuclear waste is adequate at this moment. These are usually handled by railroad; however, increased rail rates may move the shippers to truck transport.

Another important area in the transport of spent fuel elements is the number of shipping casks available. There are only two companies involved in this activity: Nuclear Fuel Services and General Electric. The highest capacity cask available, as of October 1973, is the GE F-300. This can carry seven Pressurized Water Reactor (PWR) assemblies or eighteen Boiling Water Reactor (BWR) assemblies. PWR's discharge about 120 to 200 assemblies per core replacement loading, while a large BWR averages about 360 to 760 per core loading.

### Hydroelectric

Water has been used for the production of some forms of power since Roman times. Many hydroelectric power-generation stations exist today with capacities well in excess of  $10^3$  MW<sub>e</sub>. The ultimate world capacity for energy production from this source has been estimated to be  $2.857 \times 10^6$  MW<sub>e</sub> with:

$0.780 \times 10^6$  MW<sub>e</sub> in Africa  
 $0.577 \times 10^6$  MW<sub>e</sub> in South America  
 $0.186 \times 10^6$  MW<sub>e</sub> in the United States

It is interesting to note that the fossil-fuel poor regions of Africa and South America have the richest sources of hydroelectric power potential. An estimate of the ultimate U.S. hydroelectric capacity is given in Table D.2.2-3 (U. S. Geological Survey).

Except for a few large new sites ranging from 500 to 2500 MW, the planned hydroelectric developments will include mostly small sites of less than 200 MW capacity. If planned expansions occur, about 60% of the potential hydroelectric energy in the U.S. will be harnessed by 1985. Necessarily, the undeveloped potential sources will be mostly widely scattered small sites in the 50 to 150 MW range that may never be developed for economic reasons. Laws to preserve rivers in their natural wild state may limit the development of the planned sites.

TABLE D.2.2-3. U. S. HYDROELECTRIC CAPACITY  
[U. S. Geological Survey-74]

Region	Ultimate Capacity ( $10^3$ MW <sub>e</sub> )	1972 installed capacity $10^3$ MW <sub>e</sub>
New England	6.8	1.51
Middle Atlantic	16.5	4.25
East North Central	2.2	0.96
West North Central	7.1	2.73
South Atlantic	14.5	5.47
East South Atlantic	9.1	5.22
West South Central	5.3	2.10
Mountain	32.4	6.22
Pacific	62.2	24.86
Alaska	32.6	0.08
Hawaii	0.1	0.02
	<u>186.8</u>	<u>53.40</u>

A developing trend in electric generation is the use of reservoirs to store water. Baseload fossil fuel plants and nuclear plants can be used to store water for peaking purposes. The stored water can be used as a conventional hydroelectric power when electrical demand peaks during daylight hours on weekdays. The reversible pump-turbine-generator permits water to be pumped uphill and also provides generation of electric power with the same unit when the water falls. Of course, the availability of pumped storage sites depends mostly on topography. A high head must exist between two reservoirs in the same area. Most of the planned pumped storage facilities are in the Appalachian Mountain area of the Carolinas, Virginia, West Virginia and Kentucky. Additional sites are planned in California and the Ozarks.

#### D.2.2.3 TRANSMISSION AND DISTRIBUTION (T&D) OF ELECTRIC POWER

Electric power to be transmitted is either AC or DC, and the modes of transmission and distribution are either overhead or underground. T & D, in the past, has accounted for more than 50% of the utilities' investments, and this investment is still serving the industry well.

In this section, a discussion on the cost of T & D, the voltage levels and advantages and disadvantages of DC transmission will be presented.

Cost of electric power transportation varies considerably with the terrain to be crossed, right-of-way costs, labor costs, voltage and line capacity. DC lines usually cost approximately 0.65 to 0.75 times as much as an AC overhead line of comparable capacity exclusive of terminal equipment. Cost ratios for underground to aerial transmission for equal capacity lines range from ten to one to forty to one. Labor and right-of-way costs as well as the type of cable systems and terrain being traversed affect this ratio. Cost of power transmission in urban areas will increase in the future due to escalating right-of-way expenses and environmental pressure to install underground transmission. Table D.2.2-4 lists the total unit mileages in the U. S. at the various voltage levels in 1968.

American and Canadian Electric Power Companies operate 765 KV lines. Research is now in progress for new voltage levels in the range from 1000 KV to 1500 KV. The nature of the load differs seasonably from one part of the country to another, and also load diversity occurs due to time zones. Generally, the summer and winter loads are much more comparable than in Europe due to the extensive use of air conditioning during the summer. The ratio of: (summer peak)/(peak load in the following December) is used to assess this characteristic. Transmission of excess generating capacity from one region to avoid the necessity for new generating plants in another seems to offer an economical solution.

TABLE D.2.2-4. VOLTAGE LEVELS &amp; MILES

Voltage Level (KV)	Miles
Below 69	136,000
69	82,000
115	77,000
138	47,000
230	37,000
345	9,000
500	5,000
TOTAL	<u>392,000</u>

The corresponding relationship between the cost of transmission and power transmitted is shown in Figure.D.2.2-2 for 345 KV and 765 circuits of various lengths. [Weedy-72]. One motivation behind using higher voltage levels is to maintain high efficiency of transmission systems (above 90%). Another motivation is to allow the bulk transmission of a block of electric power a longer distance for the same ( $I^2R$ ) resistive line loss.

Although most overhead transmission lines in the U.S. employ AC, DC lines are being used for long distances, large block electric transmission. Typically, DC lines show lower transmission cost than AC for lines longer than 350-700 miles.

Advantages of DC transmission are:

- Higher power capability for a given voltage level,
- Less corona loss and radio interference for a given voltage level,
- Transmission line conductors and towers are smaller for a given power capacity,
- Connection of power systems through DC transmission line leads to more stable systems operation.

Disadvantages of DC transmission are:

- Rectification high cost,
- Lack of adequate DC circuit breakers,
- Limited transmission from point-to-point (intermediate tapping-off is not feasible).

Underground transmission, as compared to overhead transmission requires less right-of-way, but is derated because:

- Inability to dissipate heat losses,
- Insulating materials manufacturing problems,
- Required short inductor compensation (because of the close spacing in trenches),
- Reliability problems and high cost of repair,
- Connecting joints and feed joints (for oil to flow from reservoirs to enter cable) represent the limiting part of a cable system,
- To remain flexible, there exists an upper limit on the overall cable diameter and hence to its conductor size.

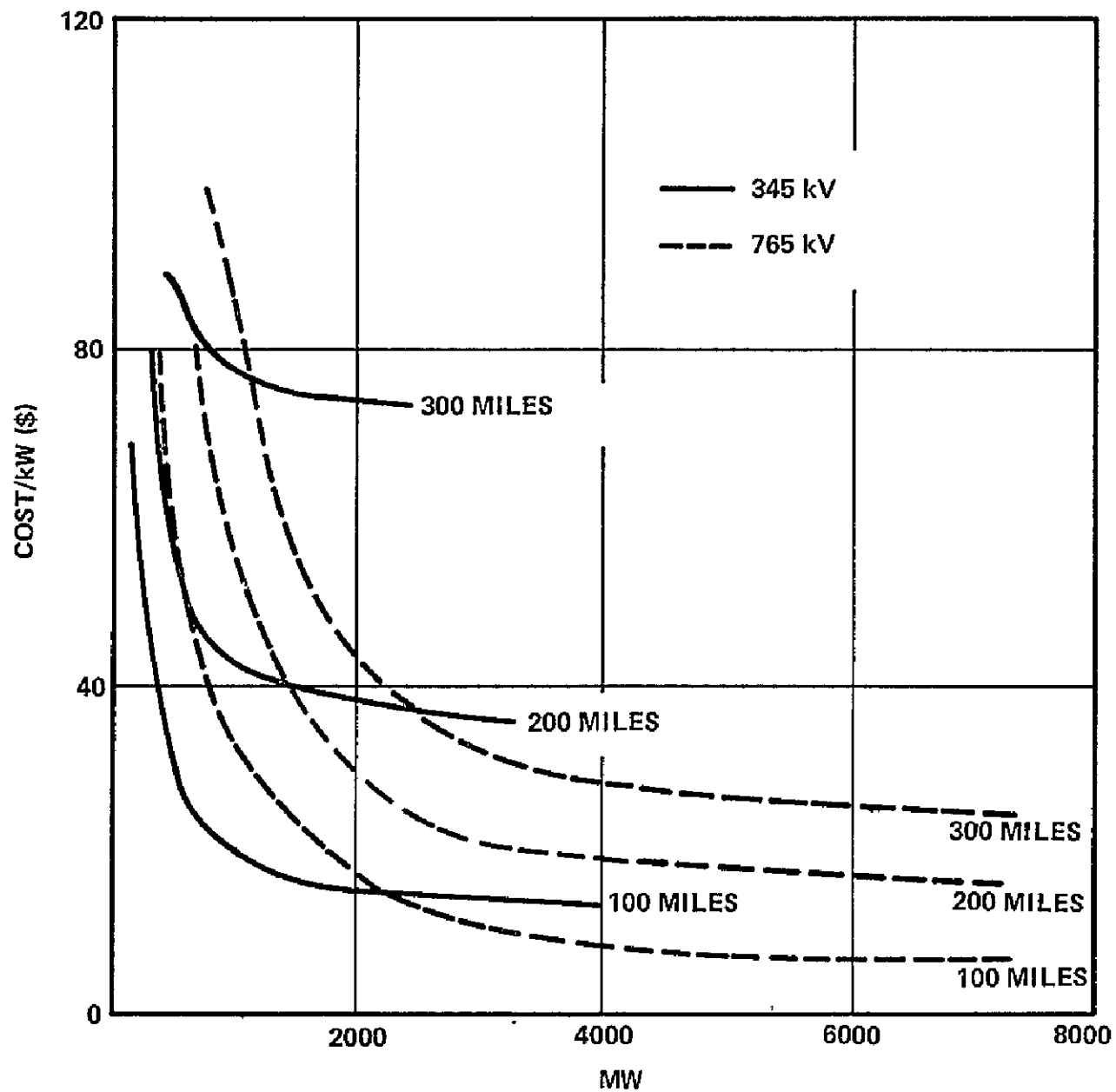


FIGURE D.2.2-2. TRANSMISSION COSTS VERSUS POWER TRANSMITTED FOR 345 KV AND 765 KV CIRCUITS OF VARIOUS LENGTHS.  
[Weedy-72]

A breakdown of costs for a 345 KV pipe type cable is shown in Figure D.2.2-3. [Weedy-72]

The losses in the AC and DC transmission are to be considered next. The ( $I^2R$ ) AC loss of the conductor represents the largest heat source. The alternating - current resistance of the conductor is the direct - current resistance modified to account for the skin and proximity effects. Skin effects even at power frequency are significant and increase with conductor cross-section. With large conductors the increase in AC resistance due to this cause is of the order of 20%. Proximity effects include the eddy currents induced in the conductor and sheath of a cable in a circuit comprising three separate single conductor cables by the conductor fluxes of the neighboring cables. Further losses are induced into steel-wire armoring wound around some cables for mechanical protection.

#### D.2.2.4 PROFITABILITY OF PUBLIC UTILITIES

Table D.2.2-5 shows some history of power industry construction expenditures and their internal vs. external origin. The most recent trend is toward external financing which generally is more costly for a given type of investment.

#### Load Factors and the Peak Capacity Problems

The utilization efficiency and production costs for electrical energy are determined, in part, by the load factor which is equal to the ratio of actually produced electrical energy to the potential annual production. The average load factor in the U. S. has been about 50% in recent years, which is slightly higher than the world average but lower than the load factor achieved in 1972 in Japan (56%) and in Canada (53%). During the same year, a load factor of only 40% was reached in England.

Electrical energy demand in the U. S. shows diurnal, weekly and annual cycles. Demand fluctuations result in cyclic peak load curves for utilities. Electric utilities are designed to meet peak demand. The plants producing electricity at the lowest cost are used to supply base-load demands, while peak demands are met by less economical generation facilities. Electrical energy prices to the consumer, financial requirements of the utilities and environmental costs involved in electricity production would all be reduced substantially by smoothing the cyclic-demand fluctuations.

The current rate design involves cross-subsidization among and between customer classes and between users who demand peak loads at different times during the day. Off-peak consumers are effectively subsidizing the users of electrical power during periods of peak demand who, at the same time, force the utilities to expand capacity and to operate less efficient generating facilities that may also consume scarce or expensive fuels. It is likely that "time-of-day" pricing (i.e., increasing utility rates according to demand) would tend to defer some of the peak loads to off-peak periods. Time-of-day meters and pricing have been used in France and have been shown to reduce peak demand.

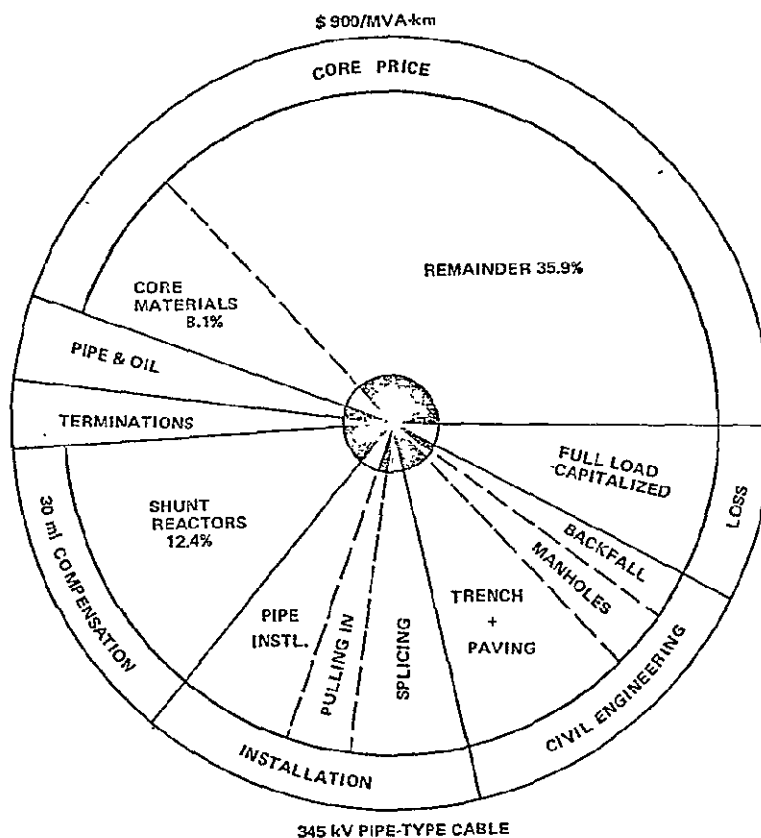


FIGURE D.2.2-3. COST COMPONENTS OF CONVENTIONAL 345 KV PIPE-TYPE CABLE  
[Weedy-72]

TABLE D.2.2-5

U.S. ELECTRIC POWL. INDUSTRY  
SOURCES OF CONSTRUCTION FINANCING  
1950 - 1974  
(Billions)

	Construction Funds Provided By			Percent of Construction Funds Provided	
	7 Construction Expenditures	8 Funds Generated Internally	9 External Financing	10 Internally	11 Externally
	(A)	(B)	(C)	(D)	(E)
1950-4	\$17.8	\$ 7.2	\$10.6	40%	60%
1955-9	21.7	9.7	12.0	45	55
1960-4	23.0	13.6	9.4	59	41
1965-9	40.0	20.0	20.0	50	50
1970-4*	83.0	27.0	56.0	33	67

\*1974 is estimated.

Sources: Electrical World, "Statistical Reports," 1959, 1966 and 1974 and EBASCO Business and Economic Charts, 1970 and 1974.

ORIGINAL PAGE IS  
OF POOR QUALITY



Projections of future productions, loads and capacities up to 1990 are given in Table D.2.2-6 for eight cases in the National Power Survey. Table D.2.2-1 gives a slightly different picture by types of plants to the year 2020. Table D.2.2-7 presents a third view that is more comprehensive.

### D.3 DEVELOPING ENERGY SYSTEMS

The energy crisis has given a new impetus to several proposed energy sources. These may represent either new uses of traditional fuels or may utilize some fuel which heretofore has not been developed. The major change has been the rapid realignment of fuel cost. Processes which as recently as 1973 were little more than a technological curiosity are now appearing economically attractive.

#### D.3.1 FOSSIL FUELS

##### Coal Liquefaction

Research into liquefaction of coal has been underway for around 50 years. The technical feasibility of such processes is well demonstrated at this time; Germany produced a significant quantity of synthetic fuel during World War II and since that time the process has undergone considerable development in South Africa. The motivation in both cases has been the same: fear of actual or threatened disruption of natural supplies.

As long as middle eastern oil remained low in cost and stable in supply there appeared little incentive to develop similar processes world wide; the situation now appears to have changed. Today a number of coal liquefaction processes are being reviewed or developed. The major processes under known development are listed in Table D.3.1-1 efficiencies and costs are generally not known. While estimates are available from the developers of each process, the recent history of cost overruns in areas involving R&D in advanced technology makes such estimates highly questionable. Present best estimates suggest costs of between \$6.40 and \$9.60 a barrel. [Ruedisili-75, 418] The lower figure applies to low sulfur boiler feedstock and the higher to refinery feedstock. Both estimates are below current OPEC prices so that economic viability of such processes appears possible.

##### Coal Gasification

Coal gasification is proceeding at a fairly rapid rate. As of March 1975 at least 29 plants are under study as shown in Table D.3.1-2. The Lurgi process used in South Africa is the best developed. Similar plants are now under development in the United States and were scheduled to begin production of low BTU gas in 1976 and high BTU gas somewhat later. [CA-75, 94] Environmentalists have filed suit to delay construction until full impacts can be assessed.

TABLE D.2.2-6. U. S. ELECTRIC POWER INDUSTRY ELECTRICAL OUTPUT, LOADS AND CAPACITIES 1970-1990 [FPC-FO-74]

	Cases I & IA	Case II	Case III	Case IV	Case V	Case VI	Case VII Modified Topping Out	For Comparison Electrical World's 25th Forecast	TAC-Power Supply Projections "Most Probable Case" 3
	Moderate Growth	Historic Growth	Low Growth	All- Electric	Zero Growth	Topping Out	Topping Out		
Electrical Output, (Trillions of kwh)									
1970 (actual) <sup>1</sup>	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	
1975	1.83	1.92	1.76	2.00	1.72	1.86	1.84	2.06	3.20
1980	2.63	2.81	2.41	2.99	1.86	2.58	2.32	2.77	4.40
1985	3.55	3.91	2.95	4.83	1.96	3.01	2.71	3.59	5.80
1990	4.64	5.38	3.42	7.40	2.09	3.16	2.99	4.64	
System Peak Loads <sup>4</sup> (Millions of kw)									
1970 (actual)	275	275	275	275	275	275	275	275	
1975	370	380	362	388	352	370	366	387	584
1980	506	539	462	570	370	494	445	514	819
1985	677	745	563	917	389	573	516	661	1,076
1990	885	1,025	652	1,411	408	602	570	849	
Total Generating Capacity (millions of kw)									
1970 (actual)	327	327	327	327	327	327	327	327	
1975	466	487	459	481	464	473	468	494	
1980	613	653	563	682	475	600	541	624	
1985	813	894	675	1,092	497	688	619	781	
1990	1,062	1,230	783	1,694	511	723	684	1,003	

<sup>1</sup> Source of 1970 actual data is "Statistical Year Book of the Electric Utility Industry," Edison Electric Institute, New York, New York. Excludes non-utility private power plant generation. The values shown in this table are given historic perspective in Figures G, H and I.

<sup>2</sup> Electrical World, September 15, 1974.

<sup>3</sup> Report to the Federal Power Commission by the Technical Advisory Committee on Power Supply, advisory to the FPC in connection with the National Power Survey.

<sup>4</sup> Arithmetic sum of system peak loads. These figures do not represent national coincident peak loads and are therefore overstated by time zone and seasonal diversities.

TABLE D.2.2-7. U. S. GROWTH COMPONENTS

YEAR	INSTALLED GENERATING CAPACITY TOTAL U. S. KW IN MILLIONS	GROSS NATIONAL PRODUCT BILLION 1974\$	CONSUMER DISPOSABLE INCOME BILLION 1974\$	BUSINESS CAPITAL EXPENDITURES BILLION 1974\$	INDUSTRIAL PRODUCTION (1967 = 100)	TOTAL EMPLOYMENT MILLIONS	POPULATION AT MID-YEAR MILLIONS	HOUSEHOLDS AT MID-YEAR MILLIONS
1963	228.7	824.6	614.6	63.1	76.5	67.7	189.2	55.6
1964	240.5	975.1	657.5	71.8	81.7	69.3	191.9	56.5
1965	254.5	1,036.7	701.2	81.9	89.2	71.1	194.3	57.7
1966	266.8	1,104.3	739.7	93.3	97.9	72.9	196.6	58.6
1967	288.2	1,133.0	769.7	93.1	100.0	74.4	198.7	59.6
1968	310.2	1,185.7	804.3	93.4	105.7	75.9	200.7	61.2
1969	332.6	1,217.6	827.9	99.5	110.7	77.9	202.7	62.5
1970	360.3	1,212.4	862.0	99.9	106.6	78.6	204.9	63.8
1971	386.7	1,250.5	895.1	97.1	106.8	79.1	207.0	65.2
1972	418.6	1,329.5	937.8	100.7	115.2	81.7	208.8	67.1
1973	452.9	1,411.0	1,003.6	108.2	125.6	84.4	210.4	68.7
1974	457.4	1,397.4	979.7	112.4	124.7	85.9	211.9	70.2
FORECAST	KW IN MILLIONS	BILLION 1974\$	BILLION 1974\$	BILLION 1974\$	PRODUCTION	EMPLOYMENT	POPULATION	HOUSEHOLDS
1975	475.7	1,433.0	975.0	116.5	130.2	87.8	213.7	71.9
1976	506.6	1,483.5	1,010.0	121.2	135.5	89.4	215.4	73.5
1977	539.6	1,516.5	1,040.0	124.8	137.8	90.0	217.2	75.1
1978	574.7	1,569.5	1,076.5	129.8	143.5	91.6	219.1	76.6
1979	612.0	1,624.5	1,115.0	135.0	149.5	93.2	221.1	78.1
1980	651.8	1,681.5	1,154.0	140.5	156.0	94.8	223.0	79.6
1981	690.9	1,723.5	1,186.5	144.7	159.0	95.5	225.0	81.0
1982	732.3	1,792.5	1,227.0	150.5	165.5	97.0	227.0	82.4
1983	776.3	1,855.0	1,270.0	156.5	172.0	98.5	229.2	83.8
1984	822.9	1,920.0	1,313.0	163.0	179.0	100.0	231.3	85.2
1985	872.2	1,968.0	1,350.0	163.0	186.0	100.7	233.3	86.6
1990	1,140.0	2,308.5	1,572.5	202.5	228.0	105.7	243.0	92.6

ORIGINAL PAGE IS  
OF POOR QUALITY

TABLE D.3.1-1

## SUMMARY OF COAL LIQUEFACTION PROCESSES

Processes	Applications	
	Refinery Feed Stock	Low Ash - Low Sulfur Boiler Fuel
Fischer Tropsch (South Africa)	Commercial	
COED	Pilot Plant	
Project Gasoline	Pilot Plant	
H-Coal	Pilot Plant	Pilot Plant
Synthoil	Developmental	Developmental
Pamco		Pilot Plant

TABLE D.3.1-2 ANNOUNCED PLANS FOR COAL CONVERSION PLANTS  
[CA-75,94]

Controlling Company(s)	Site	Process	Coal Feed, tons/day	Plant Output, million CF/day	Startup Date
El Paso Natural Gas Co.	Four Corners Area New Mexico	Lurgi gasification with methanation	28,250	288	
Texas Eastern Transmission Corp. and Pacific Lighting Corp. (Utah International Corp.)	Four Corners Area New Mexico	Lurgi gasification with methanation	102,500	1000 (4 plants)	1978
Panhandle Eastern Pipe Line Co. (Peabody Coal Co.)	Eastern Wyoming	Lurgi gasification with methanation	25,000	270	1978-80
Natural Gas Pipeline Co. of America	Dunn County, North Dakota	Lurgi gasification with methanation	108,500 (4 mines)	1000 (4 plants)	1982
American Natural Gas Co. (North American Coal Corp.)	Beulah-Hazen Area, North Dakota			1000 (4 plants)	
Northern Natural Gas Co., Cities Service Gas Co.	Powder River Basin Montana			1000 (4 plants)	1979-80
Texas Gas Transmission Corp. (Consolidation Coal Co.)	Western Kentucky			80	
Colorado Interstate Gas Corp. (Westmoreland Coal Co.)	Southeast Montana		25,000	250	
The Columbia Gas System, Inc.	Illinois			300	
Consolidated Natural Gas Co.	Southwest Pennsylvania				
Pennsylvania Gas and Water Co.	Pennsylvania	HYGAS or similar	5,000	80	
Southern Natural Gas Co.	Illinois			250	
Texas Eastern Transmission Corp. (Peabody Coal Co.)	Southern Illinois			250	
Panhandle Eastern Pipe Line Co. (Peabody Coal Co.)	Southern Illinois	Lurgi gasification with methanation			
Cameron Engineers and Ma Marathon Oil Co.	Colorado		25,000 plus sewage sludge	250	1981
Northern Illinois Gas Co. and the State of Illinois	Illinois	COED plus char gasification	10,000	80 (plus 10,000 bbl/day syncrude)	1980
Union Carbide Corp. and General Tire & Rubber Co.		Union Carbide	2,600	22 (plus 3,900 bbl/day syncrude)	1979
Commonwealth Edison Co. and Electric Power Research Institute	Pekin, Illinois	Lurgi gasification	1,400	192 (low-BTU gas)	1976

ORIGINAL PAGE IS  
OF POOR QUALITY

Costs of the Lurgi process had been projected to run between \$.90 to \$1.25 per million BTU for low BTU gas and between \$1.00 and \$1.50 per million BTU for high BTU gas. More recent cost estimates for high BTU gas run between \$2.50 to \$3.50 per million BTU.

### Oil Shale

Oil shale constitutes one of the most abundant fossil energy resources in the United States. The basic organic constituent of shale is kerogen which when heated to 900°F breaks down to form 60% oil, high in nitrogen and sulphur, about 9% fuel gas and perhaps 25% coke-like solid. Recovery rates are on the order of 15-20 gallons per ton. [Stoker-75]

Although oil shale occurs in some 30 states, only the Green River Formation, located in Colorado, Wyoming, and Utah are expected to be commercially developable at this time. The potential here is about 600 billion barrels, enough to supply the U. S. oil needs for the next 100 years at 1975 levels. Recovery is possible through mining by either surface or underground methods and by in situ processes.

The Bureau of Mines, Oil Shale Corporation and Union Oil Company of California have developed surface methods of retorting shale oil. All processes to be cost effective will require maximum heat recovery. It will also be necessary to keep water use to a minimum since oil shale is located in water poor areas. Investigations are now underway by Occidental Oil Shale Inc. to determine the feasibility of in situ recovery. Occidental has been optimistic. The company has testified before Congress that if permit problems are resolved, and progress proceeds at a reasonable pace, the method could yield 30,000 bbl/day by 1976 or 1977 and 1 million bbl/day by 1980. The process involves conventional mining, drilling and rubbleizing by explosives. Retorting is accomplished by underground burners. Two problems will have to be overcome to insure success of in situ methods: (1) permeability impediments inhibiting the passage of oil and gas will have to be resolved; (2) better control of the process than that achieved by the Bureau of Mines will be necessary.

Various estimates now exist for the cost of oil derived from shale. It appears however that a minimum requirement for economic feasibility is a market price of \$7.00/bbl of oil. [PI-74] At prices below this number, shale oil will not be able to compete.

### Solid Wastes Conversion

Three methods for converting solid wastes to a more suitable energy form are currently being investigated: pyrolysis, digestion, and methane recovery from landfills. All methods have the advantage of reducing waste disposal problems and provide an opportunity for the recycling of glass and metal. Pyrolysis and digestion abrogate many land use problems associated with waste disposal and show a marked reduction in air and water pollution when compared to open burning.

Pyrolytic conversion basically involves the destructive distillation of predominantly solid organic waste. Oil, synthetic natural gas, carbon monoxide and char are possible products. An average pound of raw waste (before removal of glass and metal) has a heat value of 5000 BTU. Pyrolytic conversions are capable of recovering 60% to 70% of this value.

Three pyrolysis processes are ready for commercialization at present; The Garrett Process (Occidental Petroleum), The Monsanto Langard Process, and The Union Carbide PUROX Process. Garrett's recovery method produces a fuel oil and provides for metal and glass recovery. The Langard process can produce either steam or fuel gas but does not have provisions for aluminum separation. The PUROX process utilizes concentrated oxygen gas to convert solid waste to a clean fuel gas averaging about 300 BTU/scf; no resource recovery is anticipated at this time.

Technological difficulties generally associated with pyrolytic conversion are no longer serious. The primary areas of concern (depending upon the process involved) are the presence of chlorine (from plastics) which gives rise to corrosion, preparation of waste (including separation of glass and metals) for processing, and providing a steady supply of waste to the conversion system.

Preliminary cost evaluations of each process have been made. [SRI-74] Indications are that PUROX may be cost effective. Including all aspects, siting, construction (amortized over a 20 year period @ 6%), collections, and disposal, a PUROX based system should realize a return of about 12¢ per ton of waste processed. This, of course, will vary depending upon the size of actual operation and the market price of natural gas.

Under anerobic conditions it is possible to generate from organic materials high quality methane. Digestion has the advantage of being compatible with both solid and liquid (sewage) sources. The process is natural but unfortunately occurs at a slow rate. Productivity can be increased by temperature control. The rate of bacteriologic degradation decreases over time so that complete digestion is uneconomical. Some means of enrichment or biologic control to improve production seems indicated.

ERDA has recently awarded a contract to the Waste Management Corporation to construct a demonstration plant in Pompano Beach, Florida. Waste Management anticipates a processing time of five days. It is expected that about 30% recovery will be possible in that short period (i.e., approximately 1500 BTU of  $\text{NH}_4$ /lb. waste materials). The effluent sludge has potential for agricultural application. Cost factors are not yet clear. A capital investment of \$2 - \$2.4 million will provide a 100 to 200 ton capacity plant (roughly  $100 \times 10^6$  BTU/day).

Proposals have been made to recover methane produced by bacteriologic action from existing landfills by drilling. A more recent suggestion has been made to design future landfill operations so that this source of energy may be exploited more readily. Only a modicum of success has been met to date, but potential prospects are being investigated. A study conducted in the San Francisco Bay area indicates the possibility of recovery of 20.9 MM scf/day of 500 BTU/scf gas ( $\approx 1,750$  EBOPD) from existing landfill sites. [VanZee-74]

### D.3.2 ELECTRIC POWER

#### D.3.2.1 TYPES OF FUEL

##### Nuclear Fuel

The fuels used in electric power generation in nuclear systems being developed included fission as well as fusion materials.

The advance fission reactor concepts under development at the present in the United States all fall within the breeder or converter category. For the fast fission breeder reactor the fuel cycle is based on plutonium and natural or depleted uranium. The thermal breeder reactor uses thorium as the fertile material and uranium-233 of the fissile fuel. Oxides of these fuels are usually fabricated as sintered pellets or contained in ceramic materials.

In the fusion reactor the basic processes for producing a controlled thermonuclear reaction are the deuterium-tritium and deuterium-deuterium reactions. Deuterium, the basic fuel, is universally obtainable from water, is virtually unexhaustible, and is obtained at a negligible cost.

##### Geothermal

The origin of geothermal heat is primarily primeval; to a lesser extent it results from radioactive decay and frictional forces within the earth's mantle. Normal heat transfer to the surface is by conduction; although, perhaps 1% of the total arrives by convection through volcanoes and hot water springs. High quality geothermal heat is confined to the Western third of the continental United States, Alaska, and Hawaii. Geothermal heat is found in four forms; hot rock, steam, hot water, and magma. Hot rock and magma formations offer the greatest energy potential but are simultaneously the least understood in terms of potential conversion.

## Solar Energy and Derivatives

The potential for recovery of energy from direct insolation is enormous; sunlight supplies the U. S. with about  $5.0 \times 10^{19}$  BTU annually. Hence, with 100% recovery efficiency, the present United States energy needs could be supplied from only 1% of its land area. Proposals have been made to derive energy from direct insolation and by indirect techniques such as wind, photo-synthesis, ocean thermal gradients, ocean currents, and waves.

Wind technology represents one of the oldest, best understood conversion methods. Surface winds are produced predominantly by uneven heating of the earth and occur in most areas on a highly predictable basis. Areas of extremely high wind utilization potential are the Aleutian Chain, areas off the coast of New England and south to Charleston, the Texas Gulf coast, and large parts of the Great Plains.

Throughout most areas of the world's oceans a distinguishable temperature difference (thermal gradient) exists above and below a roughly defined, oscillating layer of water called the thermocline. At the surface, water warmed by the sun flows towards the polar regions of the earth. Cooler water flows in an opposite direction at the lower level. Within tropical latitudes ocean thermal gradients remain relatively constant at about 35° F. D'Arsonnal, as early as 1881 suggested utilizing the thermocline differences for energy extraction. Unlike direct solar and wind systems, the ocean contains a perpetual reserve; hence outages due to availability at the source do not constitute a difficulty.

Solar insolation also provides the energy necessary to produce ocean waves and marine currents. Both have been recommended as a source of electrical conversion. Wave systems located off shore would utilize buoyant devices to drive generators through hydraulic or mechanical linkages. Ocean current systems would employ large, submerged turbines to drive generators. To date no sound empirical data has been provided for these concepts and it is doubtful that either could be utilized within the near term.

## Wastes, Source

The total amount of waste generated from urban, agricultural, and forest sources is estimated to be 945 million tons with an energy content of roughly  $2.18 \times 10^{15}$  BTU [NAS-74]. Expectations of recovery capabilities range from 20% to 50% depending upon the effort devoted to collection. Urban waste collection methods have already been established, so for exploitation of this source only organizational cooperation is required. Over 50% of the Nation's waste resources derive from agriculture; 20% of the total comes directly from animal waste. There is not only a need but with the potential for energy recovery, an incentive to utilize feed lot wastes for its energy content. Direct burning is the most efficient way to recover the potential 5000 BTU (avg) /lb in solid wastes.



### D.3.2.2 TYPES OF CONVERSION

#### Oil and Coal Fired

The cost of fuel has historically represented a major cost of electrical utilities so that there has been a continual push toward ever improved efficiencies. The average efficiency of fossil fuel plants has risen from around 13% in 1925 to about 33% in 1970. A distinct pause occurred in the generation efficiency in the 1960's. Fisher attributes much of this to unforeseen construction delays leading to overutilization of low efficiency peaking units. [Fisher-74, 96] In any case, units having efficiencies of around 37% are commonplace within industry today.

Large modern power plants utilizing fossil fuels use gas turbines, steam turbines or combined cycle units, ranked in order of increasing efficiency. Typical heat rates are 10,500 BTU/kw-hr, 9200 BTU/kw hr, and 7500 BTU/kw hr respectively. [Power-S.8].

Orders for 1974 are reported to have decreased significantly from previous years for gas turbines. Factors leading to this decrease include: (1) Potential unavailability of natural gas or liquid petroleum fuels, (2) Anticipated high costs of petroleum fuels and (3) A reduction in rate of load growth experienced by some utilities [Power - 74 14]. In terms of energy conservation this trend is generally beneficial, not only are gas turbines less efficient than fossil steam plants, but also tend to require the more scarce fuels.

The same factors which have led to a reduction in gas turbine installations have also plagued the sales of combined cycle plants. After selling a number of these units in 1971-1972, the industry has seen a marked slump in sales with only one unit sold in 1974 [Power - 74,8]. This is particularly detrimental in a developing industry where significant operating experience is important to establish the new technology. Moreover, technological developments are anticipated at a relatively rapid rate in such industries and orderly development is impeded by such events. While the combined cycle units do utilize the more scarce liquid and gaseous fossil fuels, they offer a significant long term advantage in increased thermal efficiency. The Office of Coal Research has recently funded a \$9 million contract to build and operate a combined cycle plant in conjunction with a low BTU coal gasification project. This approach promises a number of advantages over existing units [EW - April 75,37]. Not only would it be capable of utilizing the more abundant coal, but the high thermal efficiency would reduce demands on mining and rail transport expansion. Decreased thermal pollution would be additional important benefit.

The fossil fueled steam turbine plant forms the backbone of the electrical industry today. The units have a long history of development and have today achieved a proven record of high efficiency, high reliability operation. Much of the historical improvement has come about through increases in the steam temperature and pressure. The first turbine using superheated steam operated at a temperature of 513°F and a pressure of 200 psi. Current advanced units are designed to

temperatures of 1050°F and pressures of 3500 psi.

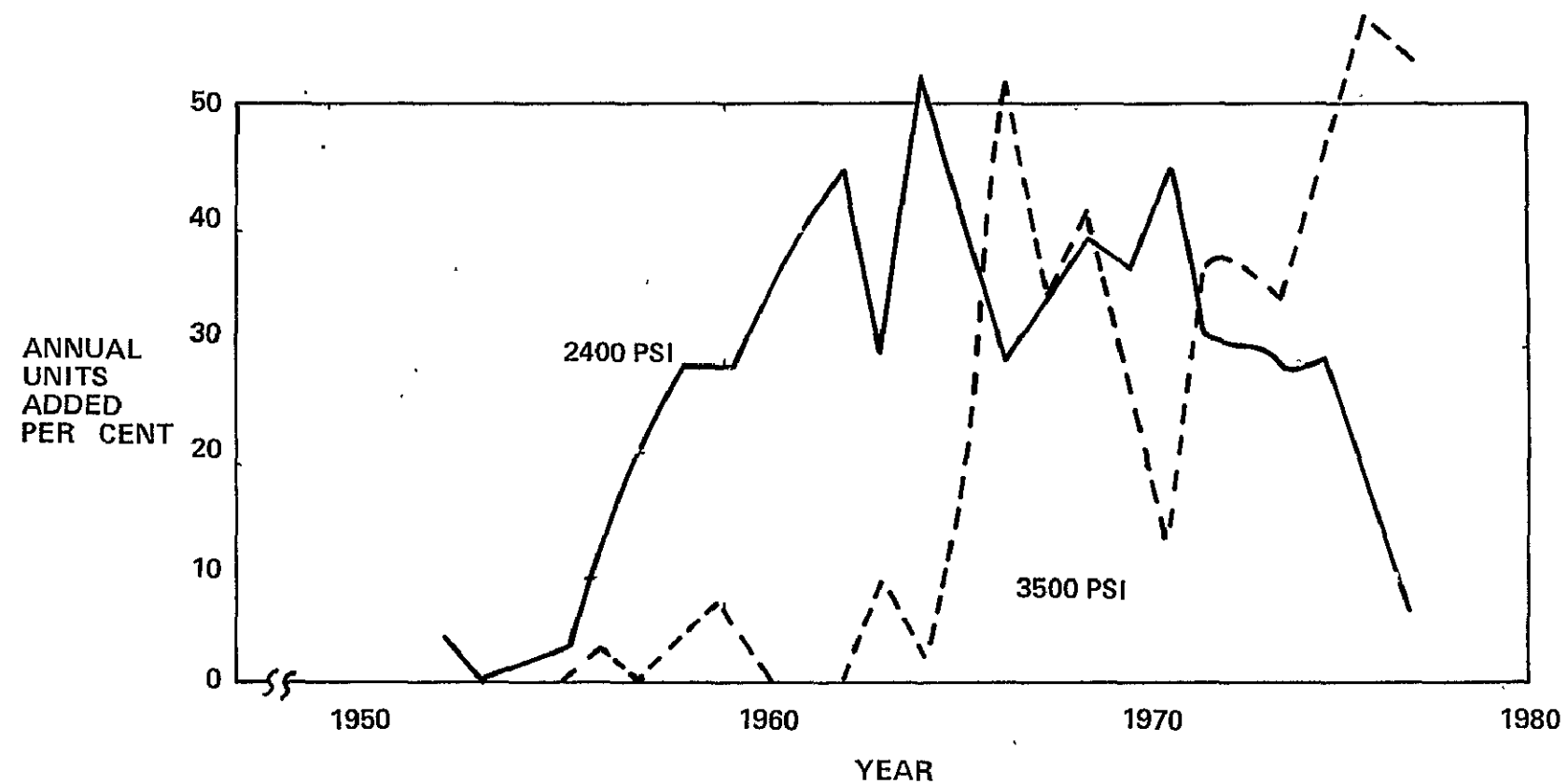
The gradual transition from the lower efficiency 2400 psi unit to the higher efficiency 3500 psi unit is seen in Figure D.3.2-1. This transition, as noted by the dip in 3500 psi units around 1970, appears irregular at times. This is attributed to a temporary disenchantment when it was discovered that the supercritical units were plagued with reliability problems. As noted in Figure D.3.2-2, the forced outage rate for the supercritical pressure units is significantly above the average for all power plants. This causes a significant fixed costs penalty for such units; not only are they more expensive to build but a more extensive back-up system is required to accommodate unexpected outages. Similar problems are encountered with high temperature units. Forced outages for the 1100°F units are seen in Figure D.3.2-3 to be well above the lower temperature units.

In view of the tendency toward high efficiency units prior to the OPEC price action it might be anticipated that increased fuel costs would provide a substantial impetus in this direction. Surprisingly no such trend has been observed. Major manufacturers report a tendency toward larger sized units to achieve an economy of scale but no detectable trend toward higher efficiency cycles [Heyburn - 75]. If anything, the largest manufacturer of fossil fired plants reports a decrease in supercritical unit sales [Tully - 75]. Market uncertainty and current economic conditions have upset much of the utility planning so that an additional time lag will be required to determine long range trends.

### Nuclear

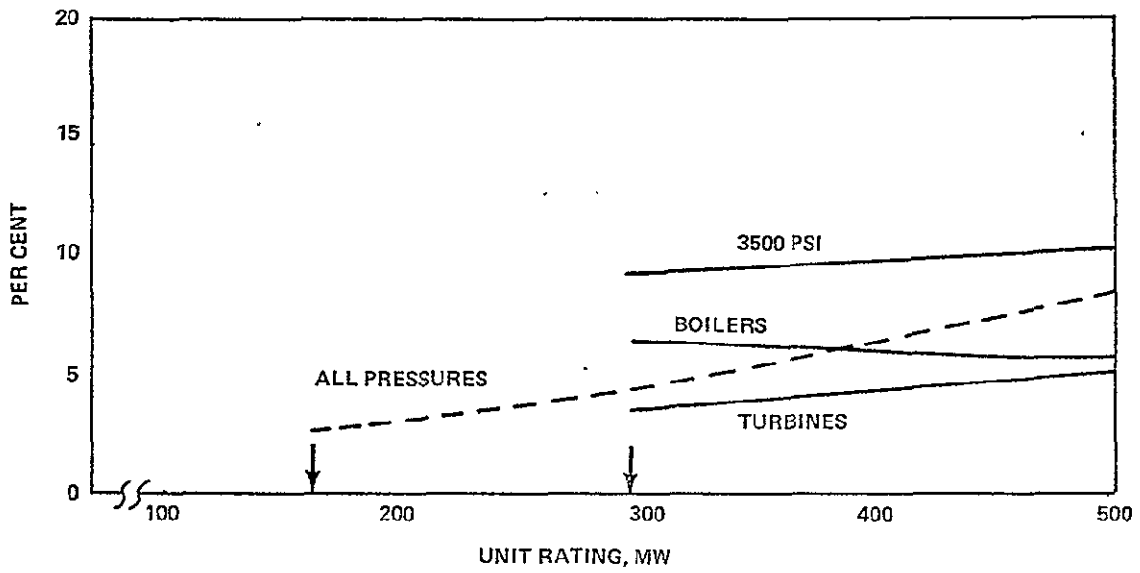
The Energy Research and Development Administration (ERDA) is developing several types of breeder reactors: 1) the molten salt breeder, 2) the light-water breeder, 3) the gas cooled fast breeder, and 4) the Liquid Metal Fast Breeder Reactor (LMFBR). However, the LMFBR program has the highest priority development effort. The LMFBR was chosen over the other breeder concepts because 1) its potential favorable performance, 2) interest and support by reactor manufacturers and electric utilities, 3) the amount of base technology and operating experience already available, and 4) proven basic feasibility. [JCAE-75]

The breeder reactor concept is based on the principle that it produces more fuel than it consumes. Since the reactor is fueled with plutonium and natural or depleted uranium, no enrichment is required, and results in significant savings in direct enrichment costs and the capital costs of building enrichment plants. LMFBR's are insensitive to the cost of uranium fuel; thus, they stabilize the cost of power generation.



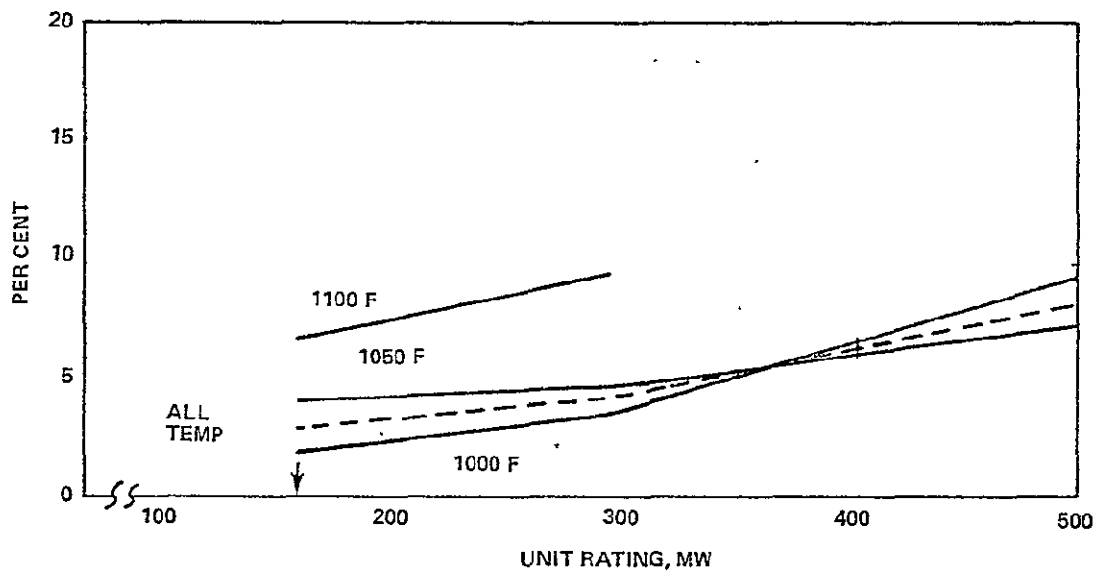
# INSTALLATIONS OF HIGH PRESSURE UNITS

FIGURE D.3.2-1



FORCED OUTAGE RATE (FOSSIL UNITS-EEI DATA)

FIGURE D.3.2-2



FORCED OUTAGE RATE (FOSSIL UNITS-EEI DATA)

FIGURE D.3.2-3

Alluding to problems in the areas of reactor safety, safeguards, health effects, and waste management, ERDA officials are reassessing the desirability of placing the breeder in wide commercial use. [NI-75] Although the recommended funding level for the LMFBR program has been scaled down, Research and Development will continue, in particular, with the Clinch River Breeder Reactor demonstration plant. Thus, the time frame for the commercial breeder reactor is in the next century.

Recent developments in fusion power research have led to the reassessment of the entire program. NRC feels that if adequate funding is provided the fusion program is in a position to proceed with large D-T fueled Physics Test Reactors at an earlier time than previously projected. A future fusion power demonstration plant is expected during 1995. [Dean-74]

### Fuel Cell

Fuel cells are electrochemical devices which directly convert hydrogen or hydrocarbon fuels into direct current electricity. Some hydrocarbon systems employ reformer processes at an intermediate state. For alternating current applications an inverter would be necessary. A variety of catalysts are possible to effect conversion, but platinum appears to be the best alternative.

At present only one company, United Technology, is actively engaged in the development of the fuel cell. Expectations of 26 MW commercial units by 1979 are indicated if sufficient development funds are available. Most of the technological difficulties seem capable of resolution. What impediments exist do so because of utility companies' demand for a reliable unit; hence reliability, not feasibility is the immediate concern. The advantages which fuel cells offer are impressive:

Very low pollution potential

Quiet operation

Can be located at or near the point where current is utilized

Operate with high efficiency at reduced load levels

Have excellent prospects for load leveling

Vitiate the need for standby spinning reserves  
(because of instantaneous load factor response)

Facilitate transmission and reduce losses

Require minimal maintenance.

In spite of these advantages, fuel cells operate at only slightly greater efficiency (about 40%) than conventional oil fired units; they do, however, offer excellent opportunity for heat recovery from cooling fluid. Cost figures are relatively clear but not yet certain. Expectations are that they will be in the vicinity of \$220 to \$240 per KWh capacity. [Podolny-75] Unfortunately, capitalization difficulties now being encountered by utility companies prohibit further extensive participation in the development of fuel cells. Emphasis on non-petroleum sources has tempered government interest in the program.

### Geothermal Process

Although steam fields are generally considered to be of two types, wet and dry, what is frequently encountered falls somewhere between these two extremes. Basically, dry steam sources, while occurring less frequently (by a factor of 1/20) than wet steam, have the advantage of being cleaner insofar as they neither contain great amounts of corrosive, dissolved salts nor involve the disposal problem of waste water laden with mineral contaminants. Dry steam sources are usually lower pressure, higher temperature than the wet variety. Systems employing either of these sources would have generally the same design; that is, they would be coupled through a desalter and/or steam separator to a turbogenerator. Because of the greater concentration of dissolved salts (~25% by wgt.) in wetter steam, separation and desalination would require greater expenditures. Some recommendations for the employment of heat exchangers have been suggested, but further investigation, with regard to both materials and mineral scaling, are indicated. Lawrence Livermore Laboratories is now working on its total flow method which would utilize both the steam and the liquid brine. A 50% overall increase in efficiency is their goal. Efficiencies of 12% from steam alone to 18% using total flow seem likely.

Hot rock sources would require the introduction of surface water through auxiliary wells. Fracturing of the rock by explosives or hydraulic pressure are a necessary prerequisite to increase the exposed area of rock. Very likely hot rock systems will encounter the same technological and material problems as steam systems. A relatively clean supply of water must be assured, or an adequate water recovery system must be included in the design. Since hot rock fields require drilling to great depths (as much as 50,000 ft.), some improvements in drilling technology will be required and fluid frictional losses due to these great depths may prove problematic.

Known costs for dry steam are now in the vicinity of \$500 KWe capacity. Hydrothermal processes are expected to be more, but estimates run from as low as \$600/KWe to a high of \$1400/KWe.

### Solar, Direct Conversion

Although excellent for low temperature (e.g. heating) applications, the energy in direct sunlight does not seem to offer immediate prospects for the economical production of electricity. Photovoltaic conversion appears to be well in the future. Costs, due to material requirements, manufacturing techniques, and low conversion efficiencies are primary factors. More highly efficient solar thermal schemes utilizing focusing or reflecting concentrators in conjunction with an absorber transferring collected energy through a working fluid to a turbine have been suggested but are only at the conceptual design stage. Outstanding problems remain to be solved. Materials capable of withstanding extreme, rapid temperature changes resulting from insolation variations will have to be found for the absorbers. Highly efficient, stable selective surfaces remain a difficulty. Other factors to be decided are the types of working fluid, and whether storage is to be provided to supply current during solar outages.

Cost figures at the moment are largely unavailable. With present batch processes, photovoltaic would require approximately \$20,000 - \$30,000 KWe (peak). Capital investment estimates for solar central generation of 3 to 5 times higher than conventional fossil fuel plants are the most recent [Spencer-75] but realistic figures will have to await operational programs. The U. S. Government intends to build a 10 MW central receiver pilot plant by 1980 which should provide cost as well as technical information.

### Solar, Wind

Conversion is straightforward. Wind driven propellers are connected to a dynamo either mechanically or through a hydraulic system. Both horizontal and vertical type systems are being studied. Technological considerations for the most part are concerned with determining system efficiency. Construction costs and material seem to indicate the superiority of the two blade vertical design.

Feasibility studies are presently in the early stages. G.E. Reports a bus-bar cost of  $1\frac{1}{2}\text{¢/KWh}$ . [Johnson-75] Construction costs have been estimated in the neighborhood of \$250 - \$1000/KWe capacity, reflecting dependency upon wind velocity and consistency.

### Solar, Thermal Gradients

Present theoretical design parameters for extracting energy from thermal gradients envisage a vertical generating plant utilizing an absorber which extracts heat energy from above the thermocline. This is transferred to a working fluid (possibly ammonia), passed through a turbine generator and rejected by a condensor below the thermocline. At this point the working fluid is liquefied and returned by a pump to the absorber.

A number of questions remain to be answered. Although some investigations and feasibility studies are available which optimistically anticipate a life expectancy of 100 years [Lockheed - 75], both technological and materials problems are likely to arise. Lockheed claims that it could have a full scale demonstration plant, over 1500 ft. in length, producing 160 MW in operation by 1981 providing bus-bar electricity at a cost of 21.5 to 23 mills/kwh. (All cost and time factors considered). The company has not provided information on transmission difficulties.

The most recent study undertaken by Lockheed has estimated investment costs to be in the vicinity of \$1,350 - \$2,594 per KW depending upon the types of materials used. It should be emphasized that no empirical basis exists for this statement.

### Electricity from Waste

A variety of proposals for direct combustion of municipal solid wastes to generate electricity are now under study. The city of St. Louis in conjunction with the Union Electric Co. has had an operational system since 1972. Most proposals involve some separation process (ferrous metals, non-ferrous metals, glass, etc.) prior to feeding combustible solids to a boiler furnace. Some of the major problems being encountered in proposed and existing systems are related to costs of separation, corrosion of boilers (largely due to PVC gasses), and high particulate emissions. Other plans which call for pyrolytic conversion of waste materials (see Section D.3.1) offer unique advantages.

### D.3.2.3 ELECTRICITY TRANSMISSION AND DISTRIBUTION [EPRI-75], [WE-64], [ERC-71]

#### Introduction:

The required capital expenditures per year between 1974 and 1990 for T&D expansion will more than double if the utility industry keeps pace with the demand for electric power. Historically, the industry has been able to double in size every decade without difficulty. This has been accomplished mainly by utilizing components with larger capacities and higher voltage levels.

Goals in transmission and distribution lie in the following classes:

- Bulk power transmission
- Tools and techniques
- Aesthetics and compactness
- System security and control
- Test facilities



Transport of electric energy must be accomplished : (i) reliably, (ii) at a reasonable cost, (iii) and with minimum environmental impact.

In transmission the trend has been a shift from 69 thru 138 KV lines to 242 thru 765 KV (EHV) and for the future to 1200 KV lines (UHV). DC transmission has become attractive and will become a major factor after 1985. Underground installations have been increasing and should continue as changing technologies become available.

Distribution trends have been from 5 KV classes of circuit to 15 KV and for the future will increase to 16 KV classes. Public pressure and legislation have also increased the percentage of new construction installed underground up to 60% or more.

Figure D.3.2-4 shows the transmission facilities of the U. S. after being grouped.

#### AC Overhead Transmission

Our most reliable and economical means of transferring large blocks of power within a power system, between power systems, and between geographical areas continues to be AC overhead transmission. With increasing reliability, it has become possible to transmit larger blocks of power without a corresponding increase in space requirements or in cost. It is apparent that there is a need not only for higher voltage levels, improved appearance, and better utilization of land, but also for the solution of problems at present voltage levels, such as corona, noise, conductor movement (galloping, vibration) and insulation. Reliable, safe and low cost AC overhead transmission is expected to expand in such a way to insure public acceptance, with minimal impact on the environment, and without a proportionate increase in the right-of-way requirements.

#### AC Underground Transmission

Underground R & D efforts lie in the following areas:

Development of Cable Test Facilities (special interest in simulating the aging effects);

Compressed Gas (usually sulfur hexafluoride) insulated cables:

Cable consisting of a conductor held concentrically by insulators in a gas-filled pipe, attractive for their simplicity and low capital investment required for manufacturing. Their losses are considerably less than any other presently available underground transmission systems;

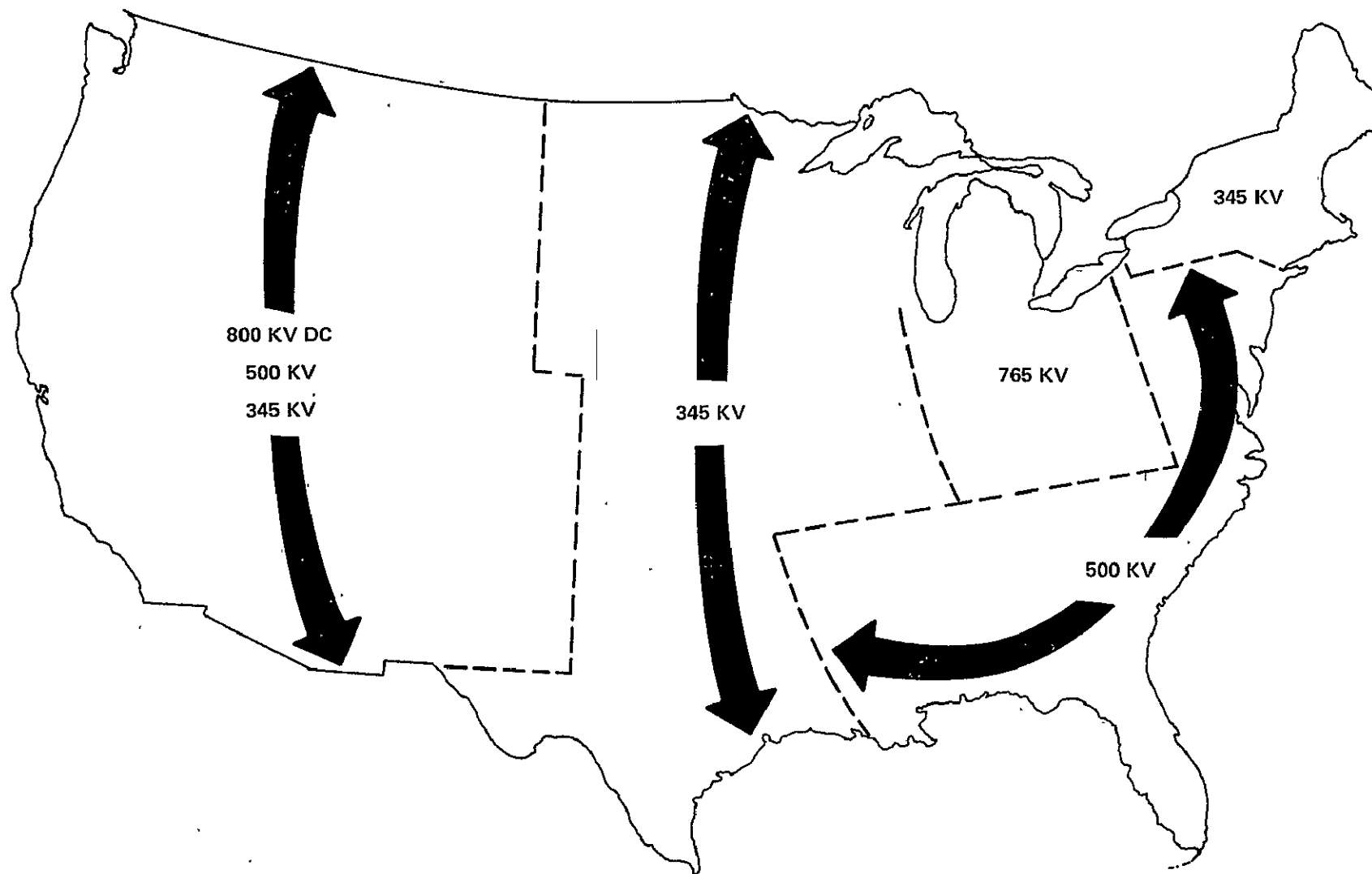


FIGURE D.3.2-4. HIGHEST EHV TRANSMISSION VOLTAGES IN USE OR AUTHORIZED

Producing lower cost cable joints and new methods for fabricating and repairing joints;

Finding improved dielectric materials to be used with or in place of cellulose tape in Taped-Cable;

Solid High Voltage Dielectric cables produced by extruding the insulation;

Forced Cooling Cables: power rating can probably be doubled at a competitive cost with a cable designed for higher rating without cooling. Refrigeration stations are required at intervals along the line to cool the oil.

Cryogenic and Superconducting transmission materials operated at temperature below 22°K offer negligible resistance to the passage of electric current. Cryogenic and superconducting cables are being developed with rated capacities on the order of 1000 to 10,000 MVA. This appears to be the sound long term solution of transmitting electric power, both from an economic and environmental point of view. The goal is to solve the problem of carrying higher power density, with lower losses, over greater distances.

Cooling is suggested by liquid nitrogen, hydrogen and helium. There is high cost involved in refrigerating the lines to low temperatures. A parameter that is usually used for comparative studies is the Refrigeration Ratio defined as refrigeration load/ $I^2R$  transmission loss. Hydrogen may offer a better compromise between the advantages of low temperature and the costs of cooling.

### DC Transmission

The capability to build a point to point DC transmission line is available, but refinement and operating experience of this technology with its hardware development is required. Emphasis is on providing design parameters for transmission lines with capacities up to 2000 MW. Basic work is required to evaluate DC lines with capacities equivalent to AC voltages up to 1500 KV to evaluate insulation requirements, effects of UHV fields as well as such factors as audible noise, radio and telephone interference factors. Improvements are also required in present day converter equipment. With the problem of space in the hearts of urban areas, research is needed to minaturize converter terminals (using solid-state technology).

It DC lines are to be widely applied and they are to be tapped, successful DC circuit breakers must be developed.

## Distribution

Distribution must go underground in both urban and suburban areas. Reliable and economical underground equipment (especially transformers and switching devices) is needed. Low cost, long life, direct buried, transformers and capacitors are high on the list of needs. Development of smaller and more compact high capacity substation equipment will improve the acceptability of substations in urban residential areas. The development of remote meter reading, data logging, alarm and control systems, as well as economical communication systems will be necessary. Installation of underground cables requires improved trenching methods as well as techniques for tapping energized primary cables safely. This will fulfill fast, low cost installation and maintenance of underground cable systems.

### D.3.3 ENERGY STORAGE SYSTEMS

Electric utility experience with pumped hydro storage has demonstrated that large-scale storage of energy can result in significant operating and economic advantages for electric power systems. These advantages, and the potential for conservation of scarce, high quality fossil fuels, have generated much interest in a number of concepts that appear to broaden the applicability and increase the usefulness of energy storage.

The basic dilemma for most electric utilities is a marked daily, weekly and seasonal variation in demand of electric power. Thus, a utility must generate power economically, over a large swing of the electric load; at the same time, its generating capacity must be large enough to satisfy the maximum demand plus, for reliability, the requirement of a sizeable system reserve.

Base load plants are used to serve the part of the system load that continues for 24 hours a day throughout most of the year. These are designed to operate with the highest level of efficiency and reliability on the least expensive fuels. Base load generation is now served primarily by modern fossil steam plants; nuclear steam plants will serve an increasing fraction of the base load.

The intermediate load range, which comprises the broad daily demand peak of a typical utility, is served by several different types of generating equipment. This equipment comprises typically a utility's older, less efficient fossil steam plants and gas turbines.

The peak load demand which may range from a few hours to perhaps 10 hours a day is usually satisfied by a system's oldest and least efficient fossil steam plant and increasingly by gas turbines.

Sharply increased fuel prices create a heavy penalty for older, inefficient equipment, and natural gas as well as high quality distillate fuels are becoming less available and more costly. Thus incentives are growing rapidly to use base load plants to also provide the electric energy now generated by peaking and intermediate equipment -- an approach that requires storage of off-peak energy generated by base load plants. The use of energy storage in "peak shaving" is discussed in Chapter 10.2.3.1.

Energy storage systems must however meet utility type standards of requirements for operating life, reliability, safety and environmental compatibility of generating equipment. Moreover, the total annual cost of electric energy obtained from energy storage systems must be equal or less than the cost of energy from non-storage equipment used for peaking.

Energy storage can take any of the following forms: thermal, mechanical, pumped hydraulic and compressed air storage systems, storage of liquid petroleum, natural gas storage, storage of synthetic fuels, chemical and electromagnetic storage. In Section D.3.4 hydrogen and its storage are examined as an excellent example of chemical energy storage.

Energy can be stored thermally by heating, melting or evaporating materials. Energy storage by heating materials to elevated temperatures is known as sensible heat storage. Energy may be stored in the form of latent heat by heat transfer to materials during a phase change for solid to liquid or from liquid to gas. A bed of crushed stones is a low cost storage medium. Water is an excellent example for sensible heat storage below temperatures of 212°F. Materials that are suitable for latent heat storage of energy are: calcium chloride hexahydrate, sodium hydroxide, lithium nitrate, lithium hydroxide and sodium fluoride.

Mechanical energy storage can be achieved by a flywheel. The potter's wheel is an example of energy storage in a flywheel. Shape factor is a term usually used and is a function of the rotor geometry and the flywheel material deformation. Shape factor is dimensionless and has a range from 0 to 1. Available energy from flywheel energy storage system is a function of the operating speed ratio which is defined to be the ratio of the highest operating speed to the lowest operating speed. The term superflywheel is used for flywheels constructed from materials such as Eglass, carbon fiber, etc. These materials have higher maximum tensile strength per unit mass than materials such as aluminum and steel. Applications of energy storing superflywheels may involve land transportation systems (golf carts, autos, busses), power supplies ranging from emergency power supplies for hospitals to electric power peaking capability for utilities, and in aircraft, watercraft and spacecraft.

Fluid mechanical storage systems include storage in the gravitational potential of a liquid (pumped hydro storage), or in the compression of a gas or vapor (air, steam). Pumped hydroelectric storage is presently the only type of energy storage in use in utility systems; these hydro systems typically achieve energy efficiencies of about 65%. Compressed-air energy storage comprising the use of off-peak generation to compress air for peak period use in turbine generators is receiving increased attention. During periods of peak demand, the compressed air would be used with an appropriate fuel to fire a turbine. High temperature steam storage for use with conventional steam turbine generators is conceptually similar to compressed air storage. Steam storage exhibits a relatively high energy density and this implies that storage in steel tanks may be economically competitive. Underground pumped hydro storage is another fluid mechanical energy storage concept. The operation would be analogous to that of conventional pumped hydro storage facilities. The lower reservoir would however consist of a subterranean cavern while the upper reservoir could be either above or below ground.

Batteries are considered a special case of chemical storage where initial conversion, storage and reversion are combined in a single device. Greater attention is now being focused on the possible use of batteries for bulk energy storage in utility systems and for electric cars.

Lead-acid batteries might become an important example of this approach if an advanced technology capable of long cycle life can be developed around cell designs that minimize lead requirements and can be produced inexpensively in volume. Technically and economically feasible lead-acid batteries for utility applications could conceivably become commercially available in about 4-5 years.

Research and development are progressing not only in lead-acid batteries but also in zinc-chlorine, sodium sulfur, lithium-iron sulfide batteries. An assessment of the potential of each battery type for utility energy storage is required. Emphasis is focused also on completing a feasibility study of a battery storage test (BEST) facility.

#### D.3.4 HYDROGEN: AN ALTERNATIVE FUEL

Hydrogen is an excellent candidate in the search for acceptable permanent energy sources that meet most of the obvious requirements for universal application in the energy consumption industries. Since it can be produced from water, it is everywhere available. It is an exceptionally clean fuel. When it burns in air, with very high energy release per unit mass, the only major reaction product formed is water. Hydrogen is an easily manageable fuel and is superior to natural gas

and oil in many engine-combustion-applications. The single important drawback is concerned with storage because the energy content per unit volume for hydrogen gas is very low and because the handling costs for highly compressed gases or for cryogenic storage facilities may turn out to be very high.

The extent and time scale on which hydrogen will ultimately become a primary fuel is largely dependent on price developments for its production, distribution, and application, in relation to price developments for competing fuels and energy sources. A 1973 evaluation of prices is given below in Table D.3.4-1 on 1970 data (Federal Power Commission).

### Hydrogen Production

Production of hydrogen as stated above will be from water using energy sources such as the sun or nuclear reactors. Nuclear reactors may be used to generate electricity, which may be then employed in the electrolysis of water. Alternatively, nuclear energy may be used to support a sequence of reactions at temperatures below 1000°K which is referred to as "thermochemical" manufacture of hydrogen. Figure D.3.4-1 illustrates design of a nuclear-reactor based hydrogen economy. [Penner-75]

Industrial water electrolyzers range in output from 500 ft<sup>3</sup>/d to more than 40 x 10<sup>6</sup>, with the largest unit located near hydroelectric installations where hydrogen is produced for the manufacture of synthetic nitrogen fertilizers. Commercial cells used in water electrolysis are either unipolar with each electrode serving as either an anode or cathode or bipolar with each side of a flat electrode serving as either an anode or a cathode. On the other hand, commercial procedure for the thermochemical water decomposition are not yet available; therefore, a definitive cost assessment for hydrogen production by application of these techniques can not yet be made. However, it is possible that the best thermochemical cycle will yield hydrogen at less than \$2.00/10<sup>6</sup> BTU.

### Hydrogen Transmission and Distribution

Hydrogen will be produced and ultimately used as a gas. The manner in which hydrogen is transmitted from the producer to the user will be one of the more important factors to consider in the overall economy of hydrogen fuel system. The most economical way to supply the bulk of the hydrogen fuel will be by gas pipeline. Thus, the hydrogen will be distributed in the same form as it is produced and eventually used. If gaseous hydrogen is converted to other energy forms for transmission, the overall efficiency of the fuel system will be reduced, since each conversion will require an additional energy input.

TABLE D.3.4-1. COST DISTRIBUTION  
[Federal Power Commission]

COST COMPONENT	Electricity	Natural Gas	Electrolytically produced Hydrogen
Production	2.67*	0.17	2.95 to 3.23*
Transmission	0.61	0.20	0.52
Distribution	1.61	0.27	0.34
Total cost	4.89	0.64	3.81 to 4.09

\*The value  $\$2.67/10^6 \text{ BTU}$  refers to an electrical energy cost of 9.1 mills/ $\text{KWH}_e$  and this same estimate is used in arriving at a hydrogen - production cost of  $\$3.23/10^6 \text{ BTU}$ .

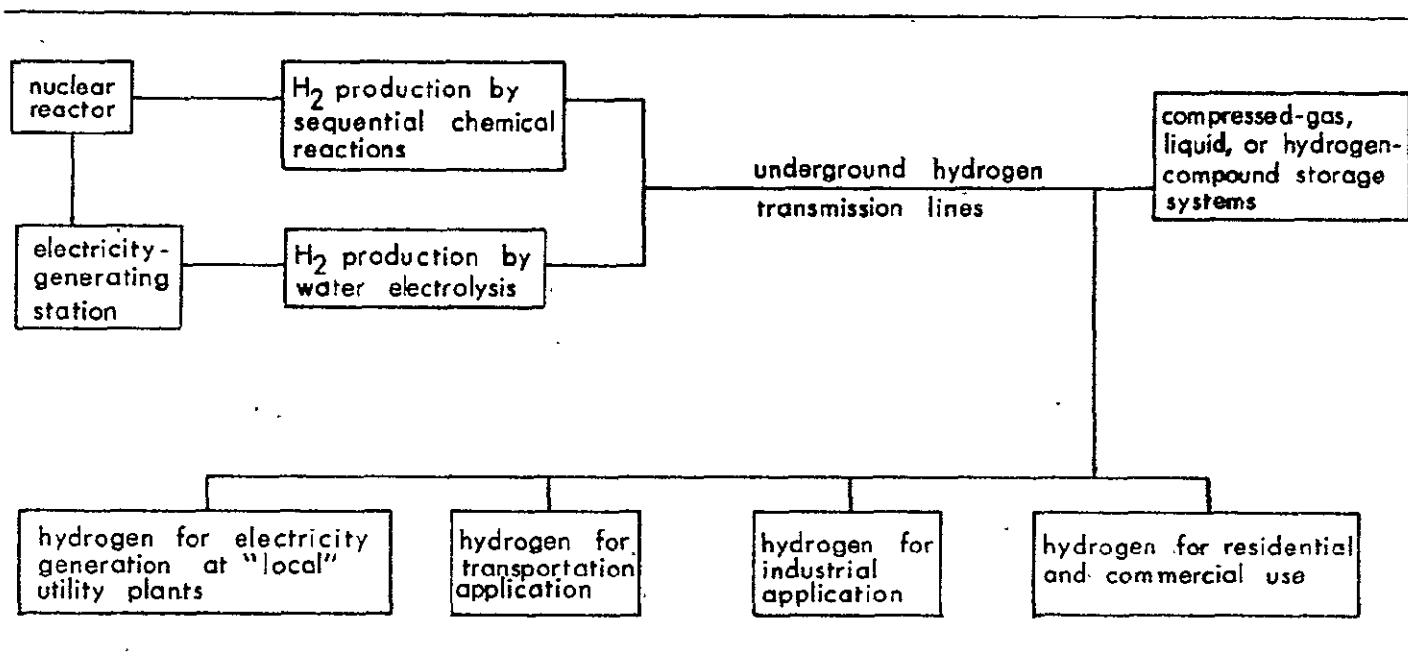


FIGURE D.3.4-1. CONCEPTUAL DESIGN OF A NUCLEAR-REACTOR-BASED HYDROGEN ECONOMY  
[Penner-75]



The experience in pipeline transmission of hydrogen in the U. S. is limited to a 50-mile network in the Houston, Texas, area. The largest and oldest hydrogen pipeline network is located in the Ruhr area of Germany where most of a 130 mile network has been in continuous operation since 1940. This pipeline has no in-line compressor station and is constructed from seamless steel pipe. In the U. S., many of the 250,000 miles of natural gas transmission network, after compressor station upgrading, are suitable for the transport of hydrogen gas. The hydrogen energy-transmission capacity of an unmodified (750 psia) natural gas pipeline is about 26% of the natural-gas energy-transmission capacity. This is due to the different compressibility factors for hydrogen and natural gas. [Penner-75] Table D.3.4-2 lists the relative energy-transmission capacities of hydrogen and natural gas pipelines operating at 750 psia. Comparison of the hydrogen and the estimated 1972 natural gas transmission costs at 750 psia indicates that the cost of hydrogen transmission is about 2.3 to 2.7 times that of natural gas.

Pipeline material compatibility with a hydrogen environment may be an obstacle to future hydrogen transmission. Although the existing mild-steel hydrogen pipelines have not been adversely affected by hydrogen, the materials used in conventional natural-gas pipeline may well be corroded by hydrogen. The term hydrogen-embrittlement is usually used to describe the molecular hydrogen dissociation at the surfaces and the penetration of atomic hydrogen into the lattice structure of steel. This usually leads to a loss of ductibility and to stress cracking, blistering or flaking. Another type of embrittlement may have been observed in hydrogen-fuel operations at NASA. Workers at NASA have categorized materials as resistant, moderately attacked, severely attacked, and extremely susceptible to attack according to their susceptibility to hydrogen-environment embrittlement. Conventional pipeline steels are expected to fall in the severely attacked category.

Many natural gas networks utilize large diameter cast-iron mains originally designed for low-pressure manufactured gas distribution in downtown areas. Suburban areas are fed through welded steel or more recently plastic pipelines. Cast iron and steel pipes are compatible with hydrogen use. The permeability of some plastic pipe compound is significantly higher to hydrogen than to natural gas and may thus limit the use of plastic distribution lines.

Liquid hydrogen, on the other hand, is transported and distributed in cryogenic truck trailers and rail cars. Truck trailer typically carry 7,000 gallons of liquid hydrogen while rail cars carry up to 34,000 gallons.

### Storage of Hydrogen

In a hydrogen pipeline system, the large-scale storage of hydrogen will be necessary for peak-shaving. The feasibility of using existing storage tanks must take into consideration the fact that a natural gas storage tank will store at design pressure only about one-third as much energy when filled with hydrogen. This may require that existing storage

TABLE D.3.4-2. THE RELATIVE ENERGY-TRANSMISSION  
CAPACITIES OF HYDROGEN AND NATURAL-GAS PIPELINES  
[Penner-75]

Pipeline	Relative compressor capacity	Relative compressor horsepower	Relative energy- transmission capacity
natural gas	1.0	1.0	1.0
hydrogen <sup>a</sup>	1.0	0.1	0.26
hydrogen <sup>b</sup>	2.1	1.0	0.56
hydrogen <sup>c</sup>	3.8	5.5	1.0

- a. An unmodified natural-gas pipeline is assumed.
- b. A natural-gas pipeline with modified compressor capacity is assumed.
- c. A natural-gas pipeline with modified compressor capacity and horsepower is assumed.

facilities be enlarged. For liquid hydrogen, however, spherical containers are conventionally used. This type of cryogenic storage system, as well as storage in compressed-gas cylinders, is too expensive for large-scale application. Because of the low boiling point of liquid hydrogen ( $-423^{\circ}\text{F}$ ), particular care must be taken to construct an effective insulating system.

Transport and storage of liquid hydrogen has undergone considerable improvement in recent years, mainly due to the large quantities of liquid hydrogen used as a fuel in the space program and the liquid hydrogen stored at the Nuclear Rocket Development Station in Nevada. [HY-73]

### The Role of Hydrogen

It is envisioned that in a hydrogen energy system there will be several areas where liquid hydrogen may be used to improve the system.

In any energy supply system, the system must furnish energy on demand, and the demand is not generally constant. If hydrogen gas were being used only for domestic heating, the fluctuations in demand would be somewhat predictable since there would be a higher demand on days. The suggestion of using hydrogen generated from off-peak power to meet peak load was made in 1933 by Erran. Recently, [T.J-74] proposed a system composed of: an electrolytic-subsystem for water electrolysis, a fuel storage capability, and a fuel cell system on a hydrogen gas turbine-alternator system to supply electrical energy during the rush load periods. Figure D.3.4-2 illustrates the power generation station with the proposed peaking unit. The analysis in this study showed that when the cost of oil increases above  $\$1.20/10^6$  BTU, this scheme becomes economically feasible using technology of cryogenic storage and gas turbines presently available.

Liquid hydrogen could possibly be useful in supplying energy to a small town when the total use rate and distance from source might make a pipeline for hydrogen gas uneconomical. Another suggested use of liquid hydrogen is in cooling a cryogenic electrical transmission cable. In this concept electric energy and hydrogen energy flow in the same pipe. The economies are a result of the reduction of electrical energy lost through line resistance. [HY-73]

Perhaps the most promising market for cryogenic hydrogen is in the transportation area. [Jones-74] About 25% of the energy consumed in the U. S. is allocated to the transportation sector. The most efficient means of transportation are by train, bus, plane and auto in about that order. Hydrogen-air turbine-driven trains, trucks, and buses are distinct possibilities. Liquid hydrogen may find its maximum near-future potential in the aircraft industry. Studies indicate that cryogenic hydrogen is essential for aerodynamic cooling of hypersonic aircraft and highly desirable for supersonic airplanes.

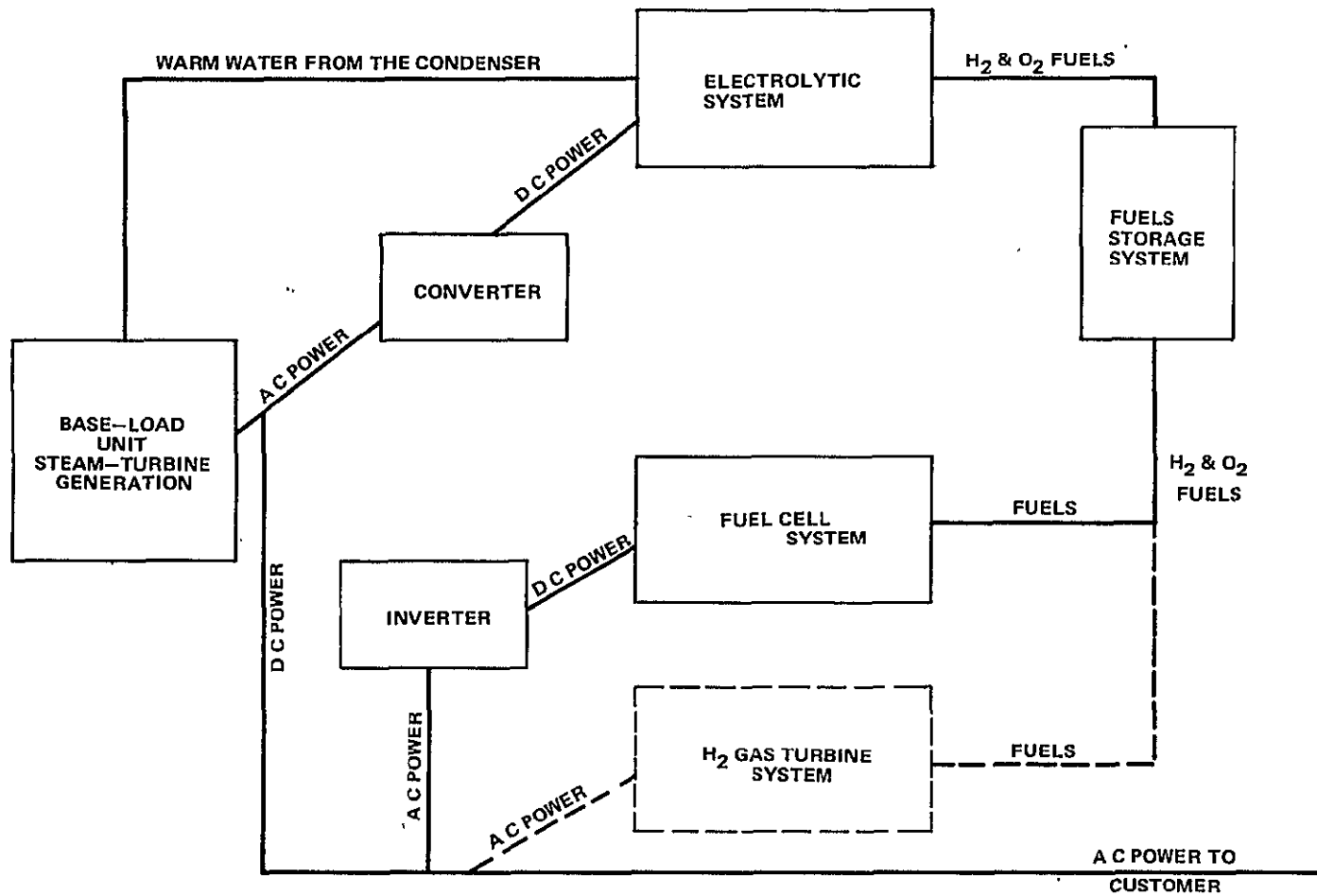


FIGURE D.3.4-2. POWER GENERATION STATION WITH HYDROGEN PEAKING UNIT

The availability of large amounts of low-priced hydrogen would have a distinct influence on industry. For example, the use of hydrogen as a direct reducing agent for the production of iron from ore has been technically proven. The switch from coke to hydrogen in the steel-making industry would have widespread effects, especially in reducing air pollution.

### Safety of Hydrogen

Safety is perhaps the most controversial issue surrounding the possible use of hydrogen as a fuel. Skeptics often express fear about the flammability of hydrogen. One should consider the improvements in hydrogen technology and safety measures that have been made since 1937 when the Zeppelin disaster took place. Many of the improvements have been spin-off benefits of the space program. NASA has scheduled the Space Shuttle for 60 flights/year, carrying  $14 \times 10^6$  lb/year of liquid hydrogen into space.

Hydrogen, today, is considered to be no more hazardous to use, transport and store than gasoline or natural gas, provided proper equipment and techniques are employed.

Hydrogen has no odor, a property that makes leaks of pure hydrogen hard to detect. Odorants are normally added to natural gas to make leaks more obvious, and the same thing can be done with hydrogen. The nearly invisible hydrogen flame might be dangerous as well; an illuminant added to the gas to increase the flame luminosity would solve the problem.

## D.4 GENERAL PROPOSED ACTIONS

This section presents a summary of proposed actions that have impact on the Energy Industry (electric utilities included). These actions resulted from discussions among the Energy Industry task group members, colleagues from other task groups, from individual speakers and from published literature. Actions are categorized below as actions taken by the Government, the Energy Industry, and other sectors (transportation, residential/commercial and processing industry). It is obvious that some actions have direct impacts not only on the Energy Industry but also on electrification. Table D.4-1 lists the numbers of all the actions categorized by the institutions that might take (or propose) them and the area(s) directly affected.

TABLE D.4-1 CATEGORIZATION OF ENERGY INDUSTRY ACTIONS

ACTIONS TAKEN BY	RELATED TO ELECTRIC UTILITIES	RELATED TO FUEL	RELATED TO TECHNOLOGY & EFFICIENCY	RELATED TO OTHERS
Government	1, 2, 3, 11, 13, 14, 15, 16, 17, 27, 28, 29, 31, 32, 36, 86	4, 10, 12, 13, 17, 21, 26, 30, 87, 88, 89, 90, 91	5, 6, 8, 20, 22, 23, 25, 33	7, 9, 18, 19, 24, 34, 35, 37
Energy Industry	38, 39, 42, 43, 44, 48, 50, 51, 52, 54, 94	92, 93, 94, 95	40, 41, 45, 46, 47, 49, 53	55
Others	58, 59, 60, 62, 76	56, 57, 63	61, 64, 69, 70, 71, 72, 73, 74, 75, 77, 78, 79, 80, 81, 82, 83, 84, 85	65, 66, 67, 68

List of Energy Industry Possible Actions

1. Investigate inverted rate structure for utilities.
2. Accentuate discount rate structure for utilities.
3. Encourage electrification by subsidizing.
4. Promote synthetic petroleum (coal gasification, shale oil, liquefaction).
5. Develop standards for power plant design (emphasizing efficiency).
6. Devise mechanisms to bring in new efficient technology by:
  - a. Taxing scarce fuels
  - b. Accelerate depreciation allowance on utilities
7. Start a major educational campaign aimed at key groups to bring them up to date on available energy conservation technologies.
8. Provide technical and financial support for waste fuel, power, and heating plants.
9. Reduce hours for TV stations.
10. Place a surcharge on all imported fuels.
11. Eliminate the oil depletion allowance and foreign tax credits.
12. Provide a mandatory program for saving waste oil and provide for efficient collection and use.
13. Stronger and better nationally organized city recycling programs (solid waste).
14. Establish import quotas.
15. Suspend energy consumptive air and water pollution requirements.
16. Larger grants to develop solar, geothermal, nuclear, and hydroelectric.
17. Preserve energy -- import and store if price is right.
18. Change school calendar to reduce energy requirements.
19. EPIC Educational Program
20. Tax credit for commercial retrofit.

21. Establish a sulfur tax on fuel.
22. Tax credits on all retrofits which reduce energy use.
23. Permit accelerated depreciation for plant improvement systems which utilize waste heat for furnace and boosters.
24. Progressive sales and/or energy taxes on water, gas, and electricity.
25. Grant or insure low-interest loans for energy efficient facilities.
26. Establish a program on solid waste recovery from government and industry installations.
27. Permit electric utilities to negotiate rates with industrial and commercial customers.
28. Require electric utilities to share load rather than purchase and operate inefficient combustion turbines.
29. Require electric utilities to make power generating unit load assignments on basis of minimum oil and gas consumption not minimum cost.
30. Expedite availability in the U. S. of an economical, practical, reliable SO<sub>2</sub> removal system. (The lack of such a system is discouraging use of fuel in existing steam power plants.)
31. Use aerospace technology to develop a solar energy generating synchronous satellite.
32. Accelerate the development of cryogenic, laser, and other energy efficient power transmission techniques.
33. Provide incentives to close inefficient plants and open efficient ones.
34. Provide special tax credits and accelerated depreciation for paper mills and others who are electricity suppliers due to efficient waste-use systems.
35. National education program informing people of methods and the need to conserve energy.
36. Require all new fossil fuel power plants to burn coal or solid waste.
37. Require that future housing development provide at least 65% of their own energy source.



38. Establish consolidated control of electric grid (power centers).
39. Encourage load management to achieve higher load factors.
40. Reduction of cooling water requirements and fuel usage by adopting power plant cycles which employ combustion gas turbines in conjunction with steam equipment.
41. Install heat recovery surface in furnace stack to increase overall efficiency of heating plant.
42. Provide a rate incentive for interruptible electric energy consumption by industry.
43. Provide a rate incentive for permanent shifting of industrial loads to daily off peak periods, to nights and weekends.
44. Institute time-of-day-metering and a rate incentive to avoid peak periods.
45. Replace defective steam traps.
46. Use flash tanks and heat exchangers to recover heat from hot condensate.
47. Reduce cooling steam flow through idling turbines to the true minimum safe value.
48. Structure rates to encourage off peak use.
49. Install thicker insulation on furnaces, vessels, and ducts containing hot gases.
50. Investigate which industrial operations will lend themselves to shifting in operating patterns (electric furnaces, glass melting, crushing and grinding in many industries are good examples).
51. Promote storage heating and cooling (in form of cold water, ice or salt) which might have an adverse effect on the loading curve.
52. Institute peak demand metering only during the periods of daily peak hours.
53. Improve efficiency of stationary diesels driving generators by adding superchargers.
54. Install small unattended hydroelectric plants at undeveloped sites on rivers and lakes.

55. Improve operating practices so as to avoid waste of fuel or other materials. This will probably require an operator training program.
56. Use battery powered electric car for urban driving.
57. Initiate an electric cab program.
58. Business close at 7:00 p.m. and on Sundays.
59. Utilize daylight whenever possible in place of artificial lighting.
60. Develop a small commercially acceptable total energy package or fuel cell for apartment houses or for individual homes.
61. More efficient air conditioners.
62. Investigate how different electric heating systems match utility system characteristics.
63. Promote synthetic petroleum (coal gasification, shale oil, liquefaction, etc.)
64. Promote use of bottoming and topping units.
65. Promote staggering working hours to reduce travel time.
66. Establish a national institute for energy conservation.
67. Establish a national clearing house for energy conservation ideas.
68. Persuade "incentive-award" companies to award housing insulation retrofits, storm windows, etc.
69. Stop leaks of steam and condensate.
70. Install heaters to recover waste heat from hot water streams such as engine jacket water.
71. Install waste heat boilers to recover heat from hot waste gases such as the exhaust of turbines.
72. Reduce steam flow through pressure reducing stations to zero for all except emergency conditions.
73. Replace old eroded or corroded impellers in existing equipment.

74. Use of hydraulic or gas expansion turbines to recover pressure energy from high pressure liquid and gas streams leaving a process mill.
75. Substitute new efficient pumps, fans, compressors, etc. for old inefficient equipment.
76. Require process industries to sell to the local electrical utility any surplus power which can be produced from industrial non-condensing turbines.
77. Adopt more efficient heater designs embodying such features as flue gas recirculation. Process unit heaters with efficiencies in excess of 90% are now available.
78. In lieu of using heating steam, attempt to exchange heat between steams within a unit and also between units.
79. Increase frequency of cleaning heat exchangers.
80. Install additional heat exchange surface to minimize temperature difference between the heating steam and the product being heated.
81. Install additional metering so that abnormal steam usage will be detected quickly.
82. Use waste heat boilers to recover heat from hot gases which otherwise would be discharged to air.
83. Install forced draft fans to improve draft conditions in boilers.
84. Install additional extended surface in convection section of boilers.
85. Revise criteria for evaluation of alternate processes and equipment selections so that the alternate selected is that one which offers the lowest total cost (including fuel cost) over the lifetime of the equipment or at least over a period of ten years or more. This measure would have a greater effect in raising the efficiency of energy use by industry than any other.
86. Adopt a policy to reduce the national growth of electricity demand.
87. Initiate taxes on automobile engine size.
88. Investigate implications of gasoline rationing.

89. Initiate government regulations for intrastate natural gas sales.
90. Program for government absorbing risk for fuel industry.
91. Make available government land for commercial oil shale mining.
92. Evaluate carefully the conservation potential for petroleum dependent systems such as fuel cells.
93. Conversion to nuclear energy based on light water reactors LWR (enriched uranium) and high temperature gas-cooled reactors.
94. Recycle plutonium.
95. Improve the inefficiency in the electrolysis process and in the reconversion of hydrogen to electricity.
96. Deregulate natural gas prices.
97. Implement secondary and tertiary recovery of oil and gas.

#### D.4.2 CONSTRAINTS

Institutional constraints fall into three broad categories -- economic, legal and social.

##### Economic Constraints

Unquestionably, and perhaps with some chagrin, it must be admitted that the overwhelming class of constraints to the introduction of any conservation technology is economic. It matters little whether a particular proposal can show a 30% net energy savings, within a free corporate structure it has little chance unless it can also show a profit. This is a major factor which must be kept in focus. In particular, attention must be given to

The cost of extraction,

The cost of retrofit,

The cost of utilizing waste resources,

The capitalization of energy and utility companies.

### Legal Constraints

There are a vast number of constraints of a legal nature which have arisen because of a desire to enhance the environment, increase profits, guard against thoughtless destruction of land, and insure social stability. Such legislative effects at both state and federal levels are commendable. But some obstructive laws are archaic while the reasoning behind others becomes unsound in light of new developments in energy. A few of the particularly important areas in which constraints need to be identified are:

- Leasing policies,
- Price controls,
- Transportation regulations,
- Environmental regulations, and
- Taxation policy.

### Social Constraints

A third area in which important constraints to conservation actions can be identified is social, which, because of developing awareness, must take into account political and environmental factors as well. A politician's views cannot be totally divorced from those of his constituents nor the public's attitudes from those of the advertising media. A lot of constraints within the social realm are completely intertwined with other interests, perspectives, attitudes and fears characteristic of specific segments of society. The most important constraints in this area which need to be identified are :

- Rising expectations of improved living standards,
- Growing concern for cleaner water and clean air,
- Desire for greater leisure.

### D.4.3 IMPACTS

Following the usual practice, the impacted areas will be classified within the general categories of economics, socio-politics, environment, and technology.

Impacts could be categorized as primary, secondary, and higher order. Primary impacts are those which result as a direct consequence of a particular requirement. Secondary impacts appear due to perturbations produced in the system by the primary impacts. To illustrate the nature of impacts of various orders, suppose that a given action requires that all new fossil fuel power plants burn coal. This will necessarily entail an increase in coal mining. Primary impacts could be more mine accidents and cases of black lung disease. These in turn produce secondary and higher impacts on the mining industry, society, and on the miners themselves. Figure D.4.3-1 illustrates the sequence of impacts generated by the required increase in coal mining. Loss of income and increased medical expenses are secondary personal impacts. Note that an increase in production cost is a third order impact generated by, say, mine property damaged during a mine accident.

Figure D.4.3-1 could be expanded to include impacts of higher order, however, the analysis becomes complicated by the fact that impacts are no longer isolated and their effects tend to overlap. The discussion of impacts in this section will be limited, in general, to first and second order;

### SELECTED GROUP OF ACTIONS

Based on the overall constraints presented in Section D-4.2, the general proposed actions have been filtered out and reduced to a smaller set which directly affects the energy industry. These actions can be classified into six general categories:

Category	Action
I	Create supplies of intermediate synthetic fuels.
II	Increase efficiency of extraction, transportation, and conversion of fuels.
III	Government control of pricing structure and import of fuels.
IV	Provide economic conditions to encourage national energy development
V	Trade-off considerations in energy conservation and environmental impacts.
VI	Trade-off land use goals against energy needs

ORIGINAL PAGE IS  
OF POOR QUALITY

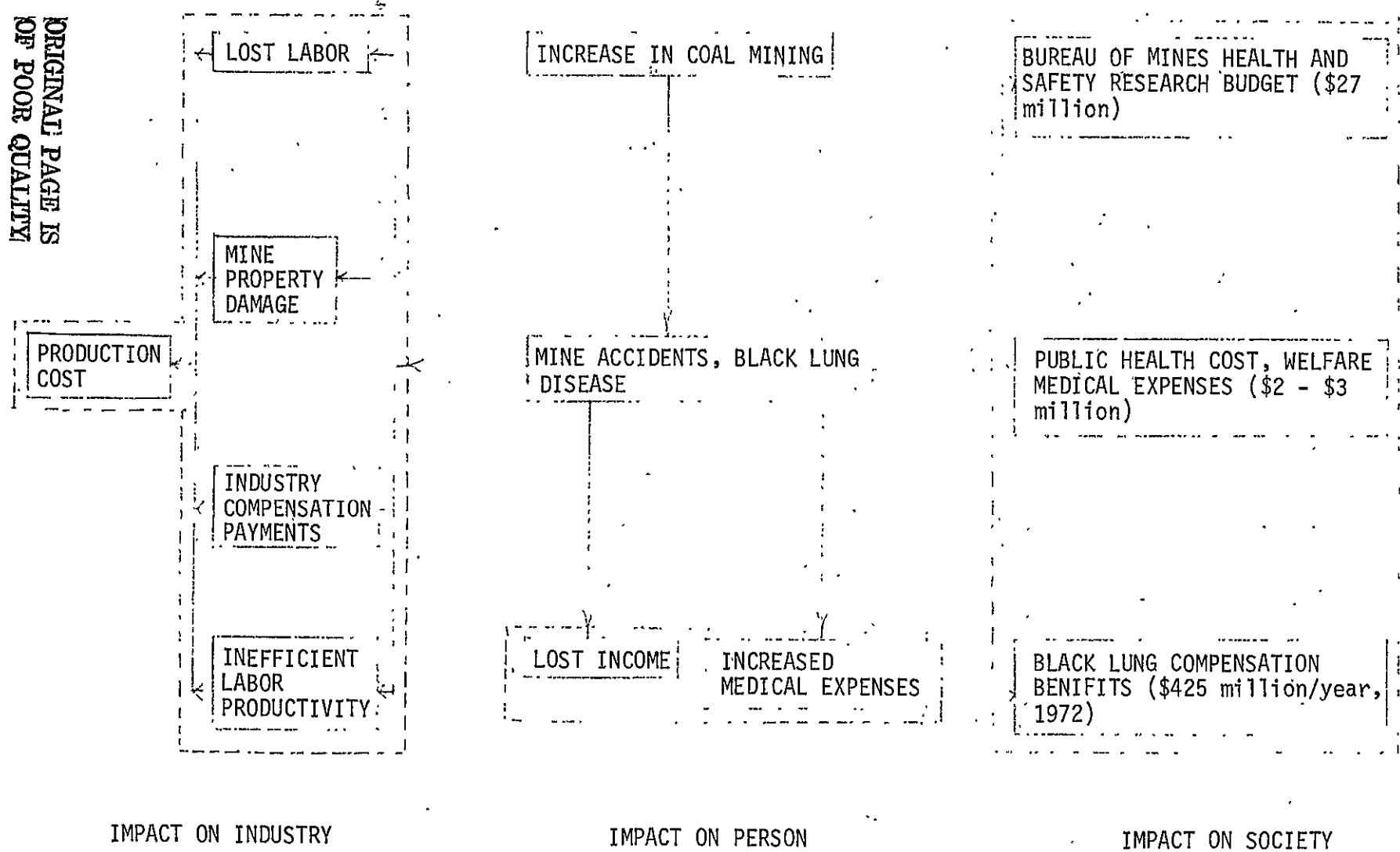


FIGURE D.4.3-1. VARIOUS IMPACTS RESULTING FROM COAL MINING

The idea of grouping the actions in general categories is to accommodate those actions which escaped consideration in the early listing, such as actions pertaining to the refining of oil

Table D.4.3-1 lists the selected actions according to the categories presented above. Action numbering is the same as in D.4.1.

### IMPACT ASSESSMENT

Actions within Category I, which includes coal gasification, in situ recovery of shale oil, and liquid natural gas; and actions number 96 and 97 are discussed in Chapter 4.

Due to time limitations, an impact assessment of only the actions within Category III and IV is presented. The basis for selecting this group of actions is their potential for immediate implementation and the fact that the government and the utilities are studying them.

Impact matrices for the technological, economic, environmental, and socio-political areas are presented in Tables D.4.3-2 through D.4.3-5, respectively. The positive sign (+) indicates that either the action produces an impact as indicated or that the impact is favorable. For the negative sign (-) the reverse is true. A blank space indicates that there is no apparent effect as far as primary and secondary impacts is concerned or that the impact is not very clear.

The assignment of relative ranking to the impacts of the actions is a subjective process. However, the method has some merit as a rough indication of effects produced by a particular action. Inspection of Tables D.4.3-2 through D.4.3-5 shows that the overall effect of the actions selected are favorable ones.

In particular, an inverted rate structure coupled with a metering system to monitor peak loads should be beneficial in the drive for energy conservation. The most widely used rate schedule encourages customers to use electricity wastefully, since the more consumed the less paid. In addition, the present price for electricity does not make any distinction between users that add to the peak load and those that do not. The utilities are legally obligated to build enough capacity to meet the peak load demand. Thus, peak load users are the cause for the requirements of more electric power plants. A system which charges the customers for the true worth of the peak period consumption will motivate people to shift to periods where system capacity is adequate and not used. The net result could be the end of unnecessary overbuilding of capacity, which could hold down electricity prices.



TABLE D.4.3-1. CATEGORIZATION OF SELECTED ACTIONS

		Category					
		I	II	III	IV	V	VI
Selected Actions			5, 6, 32, 39, 40, 41	1, 6, 10	2, 3, 6, 8,		
			45, 46, 47, 49, 53	11, 14, 17	22, 23, 25		
	4		55, 64, 69, 71, 72	21, 24, 27,	30, 33, 42	15	91
			73, 75, 77, 79, 81	29, 44, 48	43, 90.		
			83, 84, 85, 97.	96.			

TABLE D.4.3-2. TECHNICAL IMPACTS OF SELECTED ACTIONS

ACTIONS	IMPACTS								
	Specialized metering retrofit	Energy storage technology	Coal, oil or gas conversion	New electricity end uses	Distribution problems to East coast	Increase domestic exploration and production	Increase fuel stockpiles	Small scale generation plants	Large scale redesign of energy system
Inverted rate structure	-*	-	-	-					
Permit utilities to negotiate rates	-	-	-	+					
Assign load on minimum oil/gas use	-	-	-			+	+		+
Encourage off peak use	-	-	-	+					+
Time-of-day-metering	-	-	-		+		+	-	+
Sulfur tax on fuel	+	+	+		-	-	-		+
Surcharge on imported fuel	+	+	+	+	-	-	-	-	+
Eliminate foreign tax credits	+	+	+	+	-	+	-	-	+
Establish import quotas	+	+	+	+	-	+	-	-	+
Import and store if price is right	-	-	+		+	-	+	+	+
Accelerate utility discount rate	-	+	+	+	+	+	+	+	+
Subsidize electrification	+	+	+	+	+	+	+	+	+
Tax credit on all retrofits	+			+	+	+	+	+	-
Utilize waste heat	-	-	-	-		+		+	+
Loans for efficient facilities	+		+	+		+	+	+	+
Expedite SO <sub>x</sub> removal equipment			+	-	+	+	+	+	-
Encourage interruptable use	-	-	-	-	+				
Use wastes for fuel						+	+	+	-
Government accept development risks	+	+				+	+		+

\* (+) action produces an impact as indicated or impact is favorable

(-) the reverse to (+)

( ) a blank space indicates that there is no apparent effect or that the impact is not clear

TABLE D.4.3-3. ECONOMIC IMPACTS OF SELECTED ACTIONS

ACTIONS	IMPACTS									
	Energy prices	Other prices	Electric utility profits	Oil & gas industry profits	Coal industry profits	Specific utility capacity costs	Exploration and development	Energy labor demand	Small energy producers	En. ind. sector interface change
Inverted rate structure			-		-			+	+	
Permit utilities to negotiate rates			+		+					+
Assign load on minimum oil/gas use	+	+			+					+
Encourage off peak use	-	-	+		+					+
Time-of-day-metering			+		+					+
Sulfur tax on fuel	+	+	-	+	+	+	+			
Surcharge on imported fuel	+	+	-	+	+	+	+			
Eliminate foreign tax credits	+	+	-	-	+		+			+
Establish import quotas	+	+	-	-	+		+			+
Import and store if price is right	+	+	+		+		+	+	+	+
Accelerate utility discount rate	+	+	+		+		+	+	+	+
Subsidize electrification	-		+		+		+	+	+	+
Tax credit on all retrofits							+	+	+	+
Utilize waste heat	-	-	+				+	+	+	+
Loans for efficient facilities	-						+	+	+	+
Expedite SO <sub>x</sub> removal equipment	+	+	-	-	+				+	
Encourage interruptable use	-				+				+	
Use waste for fuel			-	-	+				+	+
Government accept development risks	-	-	+	+		+	+	+	-	+

\* (+) action produces an impact as indicated or impact is favorable

(-) the reverse to (+)

( ) a blank space indicates that there is no apparent effect or that the impact is not clear

TABLE D.4.3-4. ENVIRONMENTAL IMPACTS OF SELECTED ACTIONS

ACTIONS	IMPACTS					
	Reduce central pollution sources	Reduce dispersed pollution sources	More pollution control needed	Change time of day pollution	Reduce thermal pollution	Reduce biological pollution
Inverted rate structure	+	+	-		+	+
Permit utilities to negotiate rates	-	-	+		-	
Assign load on minimum oil/gas use	+	+	-		-	
Encourage off peak use	-	-	+	+	-	
Time-of-day-metering	-	-	+	+	-	
Sulfur tax on fuel	+	+	+		+	+
Surcharge on imported fuel	-	-	+		-	
Eliminate foreign tax credits	-	-	+		-	
Establish import quotas	-	-	+			
Import and store if price is right						
Accelerate utility discount rate	+	+	+		+	-
Subsidize electrification	-		+		-	
Tax credit on all retrofits	+		+		+	+
Utilize waste heat	+	+			+	
Loans for efficient facilities			-		+	
Expedite SO <sub>x</sub> removal equipment	+	+	+			+
Encourage interruptable use		+			+	
Use wastes for fuel		+	+			+
Government accept development risks	+	+	+			

\* (+) action produces an impact as indicated or impact is favorable

(-) the reverse to (+)

( ) a blank space indicates that there is no apparent effect or that the impact is not clear

TABLE D.4.3-5. SOCIO-POLITICAL IMPACTS OF SELECTED ACTIONS

ACTIONS	IMPACTS										
	Change individual life style	Change family life style	Change national life style	Change imports	Save scarce resources	Improve security of energy sources	Impact poor and fixed-income groups	Curtail waste	Change work hours	Change commuting patterns	Enhance urbanization
Inverted rate structure	+	+	+	+	+	+	+	+	+	+	+
Permit utilities to negotiate rates	+	+	+	+	+	+	+	+	+	+	+
Assign load on minimum oil/gas use	+	+	+	+	+	+	+	+	+	+	+
Encourage off peak use	+	+	+	+	+	+	+	+	+	+	+
Time-of-day-metering	+	+	+	+	+	+	+	+	+	+	+
Sulfur tax on fuel	+	+	+	+	+	+	+	+	+	+	+
Surcharge on imported fuel	+	+	+	+	+	+	+	+	+	+	+
Eliminate foreign tax credits	+	+	+	+	+	+	+	+	+	+	+
Establish import quotas	+	+	+	+	+	+	+	+	+	+	+
Import and store if price is right	+	+	+	+	+	+	+	+	+	+	+
Accelerate utility discount rate	+	+	+	+	+	+	+	+	+	+	+
Subsidize electrification	+	+	+	+	+	+	+	+	+	+	+
Tax credit on all retrofits	+	+	+	+	+	+	+	+	+	+	+
Utilize waste heat	+	+	+	+	+	+	+	+	+	+	+
Loans for efficient facilities	+	+	+	+	+	+	+	+	+	+	+
Expedite SO <sub>x</sub> removal equipment	+	+	+	+	+	+	+	+	+	+	+
Encourage interruptable use	+	+	+	+	+	+	+	+	+	+	+
Use wastes for fuel	+	+	+	+	+	+	+	+	+	+	+
Government accept development risks	+	+	+	+	+	+	+	+	+	+	+

\* (+) action produces an impact as indicated or impact is favorable

(-) the reverse to (+)

( ) a blank space indicates that there is no apparent effect or that the impact is not clear

#### D.4.4.4 GOVERNMENT PROPOSALS DIRECTLY RELATED TO THE ENERGY INDUSTRY

Appendix I contains a list of major national and state legislative proposals relating to energy. Some are categorized as energy conservation proposals, although it appears that the term is used in the restricted (simply curtail use) sense. Table D.4.4-1 presents a list of the federal proposals relating directly to the energy industry. A preponderance of bills are directed at the oil and/or gas industries, especially in the antitrust and Outer Continental Shelf areas.

The state proposals related to the energy industry deal principally with:

- Operations of public service commissions.

- State and municipal ownership of electric utilities.

- Consumer rights.

- Statewide research and development.

Some of these have already been signed by the governors of the appropriate states. The concern with the energy problem is common to all, despite the diversity in the actual state enactments.

An important area for future research is to determine the consistency of the myriad of state policies with each other and with federal policies in terms of energy conservation. The ECASTAR group has only scratched the surface by analyzing national energy conservation in light of its requirements and impacts. Government actions affect all sectors of the economy. It is difficult, then, to consider any energy conservation strategy (e.g., diversification, electrification) without direct attention to associated government policy.

#### D.4.5 DETAILED ACTIONS ANALYSIS

The basic proposals of Section D.4.1 have been screened by means of the fundamental criteria of Section D.4.2. In addition the task group added a further set of criteria. As a set the actions should cut across the disciplines of technology, economic and governmental actions. Further actions were selected to be those which are frequently proposed and which are commonly thought to be of significant impact. Where possible, alternate actions which addressed themselves to the same goal were chosen so that direct comparison could be made

The final set of actions to be considered in detail are listed below. Note that certain liberties have been taken in addressing the original proposals of Section D.4.1; this was done in order to facilitate the systems method and to enhance the direct comparability of the proposals.

<u>BILL #</u>	<u>COMMENT</u>
<u>COAL :</u>	
HR 3217	Change tax laws to encourage synthetic fuels.
HR 3333	Occupational safety.
S 1777	Clean use of coal by power plants..
HR 3463	Strip mining regulation.
HR 3836	University research on coal technology.
<u>OIL AND GAS :</u>	
S 745	Antitrust
S 1138	Antitrust
HR 3322	Antitrust
HR 3323	Antitrust
HR 3324	Antitrust
HR 3399	Antitrust
HR 4907	Antitrust
HR 5211	Antitrust
HR 5663	Antitrust
HR 6385	Antitrust
S 1113	Public oil reserves.
HR 5173	Public oil reserves.
S 1139	Outer Continental Shelf
S 1186	Outer Continental Shelf
S 1383	Outer Continental Shelf
HR 3808	Outer Continental Shelf
HR 4112	Outer Continental Shelf
HR 5043	Outer Continental Shelf
S 1182	Leasing.
S 1524	Remove depletion allowance.
S 1595	Oil Import License Fees.
HR 5510	Oil Import License Fees.
HR 3481	Coastal state funds for impact studies of OCS development.
HR 3594	Oil shale.

HR 3753	Deregulate natural gas.
HR 3850	Reduce oil imports.
HR 3876	Provide "reasonable" prices for natural gas.
HR 3906	Prohibit the President from increasing oil price by more than \$1.
HR 4061	Deny foreign tax advantages.
HR 4282	Government purchase all oil imports.
HR 5670	Government review foreign supply contracts.
HR 4958	Severance taxes.
HR 7116	Tax credit for new exploration and development.

ENERGY IN GENERAL :

HR 6557	Prohibit energy price discrimination.
---------	---------------------------------------

SYNTHETIC FUELS :

HR 6598	ERDA facilities.
---------	------------------

NUCLEAR :

S 1119	Uranium tailings
S 1717	Create nuclear power
HR 3809	Create Nuclear Power Resources Authority
HR 4945	Authorization of plutonium licenses
HR 4971	Suspend nuclear power plant licenses pending a five-year study.
HR 5406	Suspend nuclear power plant licenses pending a five-year study..
HR 6870	Suspend nuclear power plant licenses pending a five-year study.

SOLAR :

S 1379	Income tax credits on solar equipment
--------	---------------------------------------

MAGNETOHYDRODYNAMICS :

HR 5833	R & D
S 744	R & D

ELECTRIC UTILITIES

HR 3775	Environmental concerns during construction
HR 6696	Rules for agencies that regulate rates.

### Selected Actions

Coal gasification

In situ shell liquefaction

Improved secondary and tertiary recovery of oil & gas

Expanded utilization of liquid natural gas

Deregulation of natural gas prices

It should be noted that these actions address themselves to two distinct problems: (1) shortages of natural gas and (2) shortages of oil. Techniques for solution include (1) development of existing resources, (2) increases in production efficiency, and (3) introduction of substitute fuels. Detailed discussion of these alternate approaches, their requirements and impacts, are shown in Section D.4.5.1 through D.4.5.5.

#### D.4.5.1 COAL GASIFICATION

Interest in coal gasification is derived from three areas: (1) elimination of emissions associated with direct combustion of coal (2) development of a pipeline quality natural gas and (3) production of a feedstock to certain liquefaction processes. In each, coal is to be substituted for what is generally a cleaner and less expensive fuel. This action is frequently justified for two reasons:

Ultimate coal reserves are significantly larger than those of either gas or oil. Coal gasification will in the long run enable a more uniform rate of consumption.

Large coal reserves are available nationally so that replacement of alternate imported fuels impacts favorably on the balance of payments and reduces susceptibility to international boycotts.

### Proposed Action

"The federal government will develop and implement an aggressive program to facilitate rapid development of an economically viable coal gasification program."

### Goal

ERDA has considered a similar action to this for inclusion in the upcoming federal budget [Monti-75]. The government projections suggest a capability of producing 1-3 quads of gas by 1985 and 0.5 quads of liquids. In assessing the impact of such a program, a goal will be established at 3.0 quads by the end of this same time period.

## Requirements

All of the currently proposed commercial installations are based on established technology utilizing the Lurgi process [CA-75,94]. Alternate processes under development will require a significant time lag as they move through the demonstrator stage to commercial development. Commercial operations of these plants is not anticipated prior to 1985 [PI-74-3,107]. Consequently projections have been made using established costs, manpower and material requirements for the Lurgi process.

Capital costs of coal gasification plants have recently risen dramatically. In 1973 a typical unit in Dunn County, North Dakota capable of producing 250 mmcf/day ( $1 \text{ ft}^3 = 920 \text{ BTU}$ ) was reported to cost \$370 million plus another \$100 million for the mine facility [OGJ-73,132]; by July 1975 the cost of this same plant had risen to \$700 million plus \$100 million for the accompanying coal facility [Weiss-75]. This unit is scheduled to be operational in 1982. Assuming 333 days of operation per year, 37 plants are required to produce 3 quads per year. Without adjusting for inflation, this amounts to \$29,600 million which would be required to construct 37 such plants and mines to produce a 3 Quad output.

Construction and testing of a typical 250 mmcf/day plant takes three to four years. Peak manpower requirements are about 3000 employees and completion of the project requires a total of 16,550,000 man hours. This includes 250 engineers associated with the plant design and construction. Plant operation requires 625 persons and the associated mine will employ approximately 300. These numbers include 80 managers and engineers at the processing plant and an additional 65 in charge of mining. The estimated total payroll to the facility will be \$14.8 million and will support an additional 1500 to 2000 service jobs to provide increased professional and commercial service to the increased population.

Structural requirements for the proposed plants are shown in Table D.4.5-1. The pipe steel listed is for the construction of the facility itself and does not include either the water pipelines or the SRG pipeline. Since many of these units will be located in western areas where large quantities of natural gas do not normally occur, pipelines of sufficient size do not presently exist for its transport. Two of the major regions under consideration for development of coal gasification units are the Powder River Basin of Wyoming and the Four Corners area of New Mexico. Generally it is considered that gas produced in the great plains will be transported easterly either by connecting with existing pipelines in Kansas or by joining the proposed pipeline across the Canadian border. Gas produced in the Four Corners area will generally be transported toward California. Pipeline on construction costs are estimated [PI-74-6,40] at \$132,149/mmcf/day from Cheyenne, Wyoming to Kansas City, Missouri; costs are \$138,331/mmcf/day from Farmington, New Mexico to Los Angeles, California. Using an average construction costs of \$135,000/mmcf/day, pipelines sufficient to transport 3 Quads of energy per year, 8473 mmcf/day, would cost a total of approximately \$1,143,906,000. Similarly steel requirements between these locations are approximately



TABLE D.4.5-1. MATERIAL REQUIREMENTS FOR  
DEVELOPMENT OF A THREE QUAD COAL GASIFICATION CAPACITY  
[PI-74-3,47]

	Single 250 MCF/D Lurgi Unit With Methanation	3.0 Quads of Lurgi Units
Steel		
Thick Plate (tons)	24,000	888,000
Structural (tons)	7,200	266,400
Reinforcing (tons)	2,400	88,800
Pipe (tons)	12,000	444,000
High Pressure Vessels	200	6,800
Compressors over 750 HP	30	1,110
Copper (tons)	400	14,800
Aluminum (tons)	5,000	185,000

250 tons/mmcf/day requiring 2 million tons total. Manpower requirements average about 1700 man hours/mmcf/day [PI-74-6,58] giving a total of 14,405,000 man hours. Piping of water from the upper Missouri to the Northern site is expected to cost \$400-750/acre ft giving total cost of up to \$625 million [Flannery-75].

Raw process materials required for the gasification plants are shown in Table D.4.5-2. The coal is assumed to be obtained from a site adjacent to the gasification plant so that transportation problems are minimal. Oxygen is to be produced on site using cryogenic air separation. Water inputs listed include all water purchased; a portion of this water will in turn be discharged to the environment while the major portion will be consumed as a reagent. Approximately 22,000 tons of water per day will be consumed as a chemical reagent. The remaining requirements are largely for cleaning coal and for process steam.

### Potential

The total natural gas production in 1973 was 22.6 trillion cubic feet or about 23.4 quads. [PI-74-4,1-12] Limited reserves will most likely preclude significant increases in production by 1985. FEA projection of production are listed in Table D.4.5-3. Production is expected to reach only 24 to 30 trillion cubic feet by 1985. Production of 3 Quads of SNG would then represent 10-12% of the total national supply of gaseous fuels.

### Impacts

The production of 3.0 quads of SPG by 1985 would significantly decrease dependence on foreign oil supplies and alter balance of payments problems. Assuming that the produced gas could directly replace oil imports, the import requirements would be reduced by 500 million barrels per year. At \$11/bbl, this would represent a decrease of \$5.5 billion per year in oil purchases. Furthermore, natural gas supplies are critically short and service has been severely curtailed in several parts of the country. SPG can substantially augment current natural gas supplies of around 23 quads/year and help to ensure an adequate supply to the million of natural gas users.

Material requirements are considered to be a major problem. The largest need is for thick plate steel and pipe. The total requirements of steel are estimated to be 3.5 million tons to be purchased over a 3 to 7 year period. This is only a small fraction of the total 131.5 million tons produced annually (1970) [FEA-74,336], but supplies have been scarce over recent years. Similarly, if fabrication of facilities exist, vessels are no problem. The Lurgi units are designed to operate at pressures of only about 400 psi and therefore will not require specialized facilities such as those used for nuclear vessels. It should be noted, however, that again steel production is periodically strained so that manufacture of the Lurgi gasifiers may in fact delay construction of competing energy of industrial facilities.

TABLE D.4.5-2. PROCESS MATERIAL REQUIREMENTS  
FOR LURGI COAL GASIFIER

[PI-74-3;110]

	Single 250 MCF/D Lurgi Unit with Methanation	3.0 Quads of Lurgi Units
Coal	27540 tons/day	340,900,000 tons/year
Oxygen	5680 tons/day	70,300,000 tons/year
Water	40772 tons/day	504,000,000 tons/year

TABLE D.4.5-3. PROJECTIONS OF NATURAL GAS PRODUCTION 1985.  
[PI-74-4]

	Assumed Oil Price, bbl	Assumed Gas Price, mcf	Production of Non Associated Gas trillion cubic ft.	Production of Associated Gas trillion cubic ft.
Business as usual	\$ 7.00	\$1.00	18,152	5,824
Accelerated Development	\$11.00	\$2.00	21,391	7,987

Capital requirements are difficult to specify because of the rapid inflation rate encountered in the project. Projecting the costs of the Dunn County Unit scheduled to be operational in 1982 to the 37 plants, and not accounting for inflation of current or projected total U. S. capital investment, the total cost of the plants including pipelines is \$31.3 billion. In 1974 the total industrial capital investments were \$112 billion and for the oil and gas industry investments were estimated at about \$20 billion. Even spreading the costs of such units over several years and allowing for future capital expansion, it is obvious that construction of gasification plants on this scale will require a major commitment on the part of nation and will virtually preclude significant alternate actions by the oil and gas industry.

Positive benefits include significant employment opportunities in largely agricultural areas. Both the Platte River Basin of Wyoming and the Four Corners area of New Mexico are in need of additional employment opportunities. Wyoming had a net population growth of only .7% in the decade 1960-1970, with about 12% of the population leaving the state. The Four Corners areas of New Mexico is located on the Navaho Indian Reservation where employment opportunities have been traditionally poor. The total local direct and indirect permanent employment requirements are about 90,000 people. The total direct income into the community from employment by the facilities will be about \$550 million. Increased tax revenue will provide direct benefits in terms of schools, improved medical facilities and other public welfare benefits. In the short term, however, the higher influx of construction workers will over burden existing housing, schools, hospital, law enforcement, and the community services. This effect may be diminished by careful preparation and widespread use of temporary facilities, but will almost certainly produce a transient deterioration of such services for existing residents.

One of the most widely discussed issues is that of water resources. The gasification plants and associated mines will require about 740,000 acre ft/year. The increased population will require an additional 91,000 acre ft/year. Conservationists warn that "water use of this order of magnitude is a semiarid region...will have significant environmental impacts". [Ruedisili-75,149] However, the Department of Interior disagrees. Water resources will definitely limit development in the Four Corners once water supplies in the Northern Great Plains are reported to be more than adequate. [Flannery-75]. Presently about 6 million acre feet of water has been allocated to agriculture in the upper Missouri River area. Estimates of present use are only about .1 million acre ft/year. It is proposed that 1 million acre ft/year could be reallocated to coal gasification without impeding agricultural growth in the foreseeable future.

A number of alternate problems exist which are generally associated with industrial growth. These involve changes in the structure of society as the population changes from rural to urban. These include weakened community ties, growth of crime, drug misuse and numerous other social disorders. The environment will almost be degraded to some degree. Mining operations will add dust to the air. Burning coal will increase  $SO_2$  and other combustion products. Visually, homes, factories and shopping centers will replace open range and clean skies.

It is difficult to determine what the final outcome of present deliberations will be. Coal gasification now appears economically and technically feasible and few alternatives exist. Moreover improved and less expensive processes are currently under development. The number of people who potentially benefit from such action greatly outnumber those who are directly adversely effected. These considerations make future development appear almost certain. Yet those in opposition have so far been quite effective in delaying present development through various legal procedures. In the long run they can hope that technology can produce viable alternatives and that the pressures will abate.

#### D.4.5.2 IN SITU OIL SHALE

Three methods of in situ recovery of oil from shale have been investigated in substantial detail: the in situ process developed by the Bureau of Mines, the modified in situ described by TRW systems, and an alternative process under study by Occidental Oil Shale Corp. Insufficient information for an evaluation of the Occidental process is available. But some tough conjectures can be made [Bortell-75-1], [Ridley-75], [Bortell-75-2]:

The process requires no external water sources (except for re-vegetation and urban use).

The process will require about half the manpower as surface retorting methods.

Unlike TRW Systems design, the process does not retort any shale above ground.

Because of the multiple resources in the upper Colorado Basin area (coal and shale), there is a likelihood that conflicts between the two for manpower and water will arise. Substantial material and mining equipment will be needed for extensive development of in situ shale.

#### D.4.5.3 IMPROVED RECOVERY TECHNIQUES FOR OIL AND GAS

This action is a conservation measure in the simple sense that it increases the efficiency of utilization of a resource by extracting a larger percentage from known deposits. Next to management of the well itself, management of the reservoir is the key to profitable production with a long producing life. Aside from the logic of recovering as much oil as possible from known deposits to reduce the exploration risks and first costs, enhanced recovery impacts directly on any policy of finding substitutes for imported petroleum. Enhanced recovery by extending the producing life of domestic supplies does the following:

Enhanced recovery of oil and gas is a partial substitute for imports (shale oil, coal oil and gas, and exotic portable fuels or hydrogen generation). There is some potential for tapping resources such as heavy crudes and tar sands which might otherwise remain unused. Tertiary methods such

as in-situ combustion would transfer technology to other extraction processes such as shale oil. The technology and know-how would also be of great value for export or for assistance programs to developing nations. Environmental and social impacts per unit of energy are generally small with enhanced recovery methods.

In this discussion all the statistics will be based on [PI-74-2].

The gains in enhanced recovery methods will come from oil reservoirs, heavy crude reservoirs, and tar sands. Present technology of a pre-embargo vintage recovers an average of 31% of the oil in the reservoir. The recovery is estimated to rise to 39% under the assumption of \$7/bbl oil. Recovery may exceed 50% in some fields with prices at \$11/bbl. The model parameters for a typical reservoir will give a simple picture of the effect of advanced recovery on well life. The primary life of the well is taken as 5 years and the secondary and tertiary lives as 5 and 20 years, respectively, at much reduced production levels. The implication is that most wells are on secondary recovery. In the area of stable oil prices when economic incentives for advanced recovery were weak and the technology was not very advanced, massive shut-ins of wells occurred. There is limited potential for reopening wells once shut-in.

The overall potential for secondary and tertiary recovery techniques is large. As a percentage of oil already produced plus an addition to new production, enhanced recovery is large both in total (as much as a 30% addition to the recoverable fraction) and large in near term impact (as much as 20% of domestic production by the 1980's). This oil produced by enhanced recovery constitutes a contribution to saving fuels needed to ride out the transition to others with larger resource base or to intermediates requiring development.

The status of enhanced recovery technology is good and improving. There are a pool of trained personnel and a well developed industry and supplier chain. The training and education programs exist for expanding the manpower base. It has been proposed in the Department of Interior's 5-year R & D Programs (June, 74) that \$300 million be spent on enhanced recovery research and development. A further amount has been allocated for other programs such as heavy crudes and tar sands.

The technology of secondary recovery is basically water flooding (90%) and other injection schemes (10%). Tertiary recovery involves more elaborate flooding programs using more expensive media or more complex cycles of operation. It also includes combined mechanical (explosive or hydraulic) working with chemical or thermal stimulation.

The principle requirements of enhanced recovery are an attractive threshold price and the requisite investment. The threshold price can be estimated from additional investment per barrel of added reserves. The estimated secondary recovery investment today ranges from \$0.32 in the Gulf to \$0.96 in Alaska per barrel added. Tertiary investment is estimated to range from \$0.80 to \$1.68 in the different oil regions. Enhanced recovery costs are projected to double or more by 1988. [PI-74-2,111-22] Present Congressional thinking would allow for some fraction of old oil to be sold at a ceiling price of \$7.50 relative to the \$5.25 ceiling and bona fide tertiary recovery projects to have a \$8.50 ceiling. This pricing

structure proposal is discussed more fully in Chapter 9. There is the intent to eventually erase the price differential on domestic oil except for OCS and Alaska.

The material requirements specific to enhanced recovery are minor. In general they represent the same distribution of materials as primary production. Sheer size of the requirements is not a deterrent to the programs visualized in Project Independence. Water use is very small compared to the consumption in processing fuels. Also the water or fluid drive is usually made up of whatever is on hand: brine, CO<sub>2</sub> and some natural gas liquids. Tertiary recovery will require specialized chemicals. The demand for these and other supporting goods and services will expand the infrastructure of well service companies and create some new opportunities. There is also a large material recycle program inherent in enhanced recovery work. These old wells supply a good fraction of the pipe and equipment needed to implement advanced recovery.

The impact picture for enhanced recovery is in general favorable, especially for secondary projects. Tertiary recovery, particularly unproven methods such as in situ or microbiological methods, lack either history or assessment of impacts. Prolonging the life of a production site contributes a proportionate environmental load each year, but, to counter this, it reduced the expansion of oil production into new territories. The initial drilling and production periods have greater environmental impacts than the long term stable operation phase. Initiating new recovery methods introduces a transient load on the environment. Insofar as enhanced recovery substitutes for other intermediate fuel forms, such as shale oil and coal conversion, it should be credited with large net savings in environmental impacts. Since enhanced recovery potential is still small compared to our long term fuel needs, the impact of these other energy conversions is delayed, not prevented. The economic life of communities and firms tied to old oil fields will be prolonged.

The actions discussed above leave out one important alternative -- nuclear stimulation of gas. The recent experience with this method has not been encouraging. Real problems exist with yield, seismic hazards, entrained radioactive materials, cost and net energy return. Opposition is growing to the point of passing state laws forbidding nuclear explosions.

#### D.4.5.4 IMPLEMENTING OF LIQUID NATURAL GAS

Goal: In Chapter 4, section 4.5.2 the implementation of LNG as a source of energy was recommended as a means of solving some high-demand problems, by supplementing domestic natural gas supplies, and to provide gas during periods of base-load use. In this section, the technology, costs, potential, and impacts of implementing this action are examined.

##### Background and Requirements

One of the problems with NG is that it occupies a comparatively large volume per unit of heating value compared to solid or liquid fuels. Thus, it cannot be transported economically except in pipelines, and it

is difficult to store at the sites where it will be used. Converting gas into liquid helps overcoming these problems; this change results when the gas is cooled to  $-259^{\circ}\text{F}$  or  $(-161^{\circ}\text{C})$  and the resulting 600:1 reduction in volume is outstanding. The LNG technology originated some 30 years ago and was applied initially to provide gas during periods of high demand. While the use of NG by industry is quite steady year-round, the demand for heating gas in the residential and commercial areas increases during the winter. When the demand for NG exceeds the pipeline capacities, the previously formed and stored LNG is regasified and used to augment the NG arriving by the pipeline. Most LNG used during peak demand periods is produced domestically. On the other hand, foreign LNG was first imported during 68-69 by Boston Gas Co. from Algeria.

As stated earlier, using LNG helps in solving high-demand problems and can be used to provide gas during periods of base-load use. The potential of LNG world market lies in the fact that some oil-producing countries do not have much local demand for NG that is produced along with oil, and also have no large markets accessible by pipeline. Converting NG to LNG, shipping it by tanker to a consumer area where it is regasified, and delivered by pipeline to consumer represents an excellent solution. Although domestic movement of LNG is not large, importation such as from Algeria, Libya, Siberia, and Alaska by LNG tankers may become significant. As an example of the approved projects for LNG importation to the U. S. is the plan to import an equivalent of one billion cubic feet of NG/day from Algeria where full production is expected by June, 1977. The following data is selected from the U. S. Senate Subcommittee Hearing on May 1, 1973, page 481, and it illustrates the contribution in trillions of cubic feet of LNG imports to total U. S. natural gas supply.

	<u>1975</u>	<u>1980</u>	<u>1985</u>
Total NG Supply	24.2	26.9	29.5
Estimated LNG Imports	0.2	0.9	1.6
LNG as % of Total	0.81	3.31	5.41

The technology of importing LNG requires:

gas liquefaction facilities to be constructed in the exporting countries,

heavily insulated cryogenic tanker for transoceanic shipment to be provided, and

regasification and storage facilities to be constructed in the importing country.



The costs of LNG importation are relatively high, for example, the project with Algeria mentioned above requires a total investment of about \$1.7 billion. The breakdown of the cost is as follows:

liquefaction facilities	\$ 350 million
cryogenic tankers (\$80-90 million each)	1150 million
regasification facilities	200 million

Tankers will be over 900 feet long and have a capacity of 125,000 cubic meters.

#### LNG Ocean Tankers

Table D.4.5-4 summarizes the LNG ship construction potential and ship requirements. This Table indicates that the U. S. has the potential to build 72 LNG tankers between 1977 and 1985. Table D.4.5-5 shows a requirement potential of 137 U. S. vessels between 1977 and 1985, or almost twice as many as can be produced here. [Pastuhov-74] However, the two Russian projects along represent 45% of the U. S. total requirement. The U. S. shipyard industry consequently faces two major unknowns in gearing its production capacity--the actions of the Federal Power Commission and the political uncertainties of the 1981-1985 period, which requires an estimated 75 ships compared to 62 in the 1977-1980 period. Obviously, the LNG tanker business must be considered simultaneously with the petroleum crude oil carriers but, there again, the shipyards face another unknown - Congress -- which may or may not pass a minimum U. S. shipping law for oil imports.

#### Impacts

A crucial issue arising from future LNG imports is the same as with oil -- the foreign policy benefits or dangers growing from the transaction. In some cases, the government may wish to approve a transaction even though the Federal Power Commission (FPC) believes the price is too high. The decision whether to turn down such a transaction, which may be part of an overall settlement of the cold war with the Soviet Union, should be made by the President and not determined by the FPC.

As imports of LNG become a significant element of energy supply, a new government intervention enters the picture. LNG imports are being heavily subsidized by the federal government. The government pays about half the cost of the LNG tankers built in the U. S. and through the Export-Import Bank the American taxpayer is assisting in the financing of liquefaction plants built abroad.

TABLE D.4.5-4. LNG SHIP CONSTRUCTION POTENTIAL

A. Total Worldwide Shipyard Capability (120,000 m<sup>3</sup> min. capacity).

	<u>Shipyards</u>	<u>Construction berths</u>
U. S.	6	14
Western Europe	37	41
Japan	9	24
	<u>52</u>	<u>79</u>

## B. Potential for LNG Construction

	<u>Shipyards</u>	<u>Berths</u>	<u>Ships/Year</u>
U. S.	3	6	8
Western Europe	12	12	12
Japan	4	6	8
	<u>19</u>	<u>24</u>	<u>28</u>

## C. Potential number of LNG Ships Delivered:

	<u>1977-1980</u>	<u>1981-1985</u>	<u>Total</u>
U. S.	32	40	72
Western Europe	48	60	108
Japan	32	40	72
	<u>112</u>	<u>140</u>	<u>252</u>

TABLE D.4.5-5. LNG REQUIREMENT POTENTIAL

ORIGINAL PAGE IS  
OF POOR QUALITY

Imports	<u>Number of Ships</u>		
	<u>1977-80</u>	<u>1981-85</u>	<u>Total</u>
A. To the U. S.			
Algeria	6	13	19
Nigeria	14	14	28
S. America & Alaska	11		11
Pacific/West U. S.		17	17
USSR/East U. S.	20	20	40
USSR/West U. S.	11	11	22
	<u>62</u>	<u>75</u>	<u>137</u>
B. To Western Europe	10	10	20
C. To Japan	25	25	50
Total Ship Requirement	97	110	207

With LNG being a mixture of methane, heavier hydro-carbons, nitrogen and some lighter gases, the composition of the liquid can be substantially different depending on the source, time in transit, and time in storage. The effect of weathering is important to more accurately predict LNG properties such as density, composition, and heating value.

Long-term operating experience, an important factor in any shipowner's mind, is still an extremely rare commodity in the LNG business.

LNG ship prices will not be reduced below their present levels and, in fact, will probably continue to rise. This means that transportation costs in any LNG scheme will continue to account for a very large share of the total price of delivered gas; as high as 50% or more. It is highly significant to note that ship capital costs account for about 80% of total charter hire costs. Shipbuilding prices are all-important in any LNG import scheme, and in some cases will be determining.

The high costs of LNG importation makes it necessary that long term contracts be established between importers and suppliers. This has some security implications in the sense that the small number of facilities makes it much easier for production to be interrupted than is true for crude petroleum production and export.

The major environmental concerns are the human health and safety impacts of any accidental spill or fire associated with transporting huge amounts of LNG.

In summary, against the above mentioned disadvantages, LNG has several advantages and a number of its properties make its use attractive. It has an octane rating well above 100 without the addition of antiknock additives, it is clean burning and produces minimal air pollution, its specific energy per pound is .15% greater than gasolines, and it can be used as an engine coolant before it is burned as a fuel.

#### D.4.5.5 DEREGULATE NATURAL GAS PRICES

As mentioned in Chapter 4, Section 4.5. , the American Gas Association has developed an elaborate computer simulation model called TERA (Total Energy Resource Analysis). Table D.4.5.5-1 summarizes the results on one simulation that assumed:

New natural gas prices are deregulated in 1975.

Old gas prices would follow current contractual agreements.

As a result of deregulation, gas prices jump this year and rise thereafter with the 5.5% inflation rate.

It is obvious that \$11/bbl. oil evokes more gas production response as well as higher gas prices. Supplemental sources (such as imports and syngas) which are used to cover demand shortages are less important under the \$11 oil prices. With reference to residential space heating, natural deregulated gas remains the cheapest per-BTU source of energy. These results must, of course, be qualified by the assumptions mentioned above. (Of special importance are

TABLE D.4.5.5-1 NATURAL GAS PROJECTIONS [AGA-75]

		1975	1980	1985
Prices of New Gas (\$/Mcf)	a	1.28	1.67	2.08
	b	1.96	2.56	3.19
National Average Price (\$/Mcf)	a	.44	1.03	1.72
	b	.55	1.56	2.66
Total Production (Tcf)	a	21.4	22.1	23.9
	b	21.4	23.3	25.9
Total Marketed <sup>c</sup> (Tcf)	a	18.1	21.8	27.6
	b	18.3	22.7	29.2
Demand Shortage (Tcf)	a	1.4	4.4	8.8
	b	1.6	4.0	1.8
Comparison for Space Heating: National Average Price (\$/MMBTU)	Gas	a	1.63	2.63
		b	1.73	3.04
	#2 Oil	2.71	3.61	4.84
	Electricity	6.63	8.43	10.82

a. BTU equivalent to \$7.50/bbl. oil.

b. BTU equivalent to \$11/bbl. oil.

c. The difference between total production and total marketed is that all process losses are subtracted and all imports and syngas added to the latter.

the one-shot jump in natural gas prices, and, after that jump, the constant RELATIVE prices (i.e., they all go up at 5.5% per year) of gas, oil and electricity to 1985.) A more careful scrutiny of the AGA model could not have been undertaken due to time constraints.

Although calculated under different sets of assumptions, the long-run cross-price elasticities (cf. Section 1.2.1 of Chapter 1) of coal, gas and oil as calculated in Project Independence [PI-74,AII,60] are positive. This means that in most uses the three are substitutes. The same holds true for electricity as it relates to gas and oil.

Figures 1.2.1-1 and 1.2.1-2 in Chapter 1 show schematic diagrams of consumer and producer activity respectively. They combine energy resources with material goods and services to generate their desired outputs. The producer activity diagram may also depict energy producers themselves. This gives us the key to both the supply and demand forces that, under government regulation, determine market prices.

In a true interactive model, as the price of natural gas goes up, the demand for it will go down. The demand for coal and oil would initially increase if their prices have not immediately changed. As a result of increases in demand, the prices of coal and oil are expected to increase.

As natural gas prices increase, supply will go up. In conjunction with increases in oil prices, exploration and production of oil and associated gas, as well as non-associated gas, will increase. In response to higher coal prices, coal supplies will increase. The technological and economic feasibility of these supply increases are discussed elsewhere in this report.

In a dynamic-interactive model, the activities of the preceding period have important influence on the current one. Hence, depending on the RELATIVE prices of coal, gas, and oil, consumers and producers will substitute energy sources. As noted elsewhere, these substitutions involve varying degrees of back-up technologies. Since it cannot compete with the more sophisticated computer models of other studies such as Project Independence (even they admitted to the shortcomings of partial analysis), this report will contain no projections on substitutions by the various economic agents. Furthermore, the energy industry group was not disposed to juxtapose assumptions, and try to predict the uncertain future.

The economic impacts of deregulation beyond those related to other energy sources will most likely be:

Energy price increases may directly and indirectly erode purchasing power.

Domestic inflation may cause American goods to be less attractive on world markets.

There may be less reliance on OPEC oil.

Alternative (diversified) sources may become more attractive as fossil-fuel prices rise.

Employment patterns will most likely shift.

Purchasing power is increased directly by the fuel price increases and indirectly in those industries that use these energy resources as intermediate inputs. The poor bear a heavy burden during periods of real income erosion. If American inflation (including that induced by energy price increases) is greater than that of other countries, U.S. goods will be relatively more expensive. Our balance-of-trade may be affected in a negative direction. The reverse effect would be the result of a decreased dependence on the currently high-priced Arab oil.

Alternative sources (for example, oil shale, syngas, synoil, solar, wind, geothermal) may become more attractive as the BTU-equivalent prices approach or even slip below the analogous prices of the fossil fuels.

If accelerated development takes place in fossil fuel industries, the demand for engineers and other manpower will obviously increase. Coal and uranium mining areas will be attracting workers from other areas and occupations. High gasoline prices may have detrimental effects on the auto industry, causing more unemployment there. Airlines may experience the same phenomenon.

It is difficult to speak of a manpower shortage during times of high unemployment, except possibly the higher skill levels.

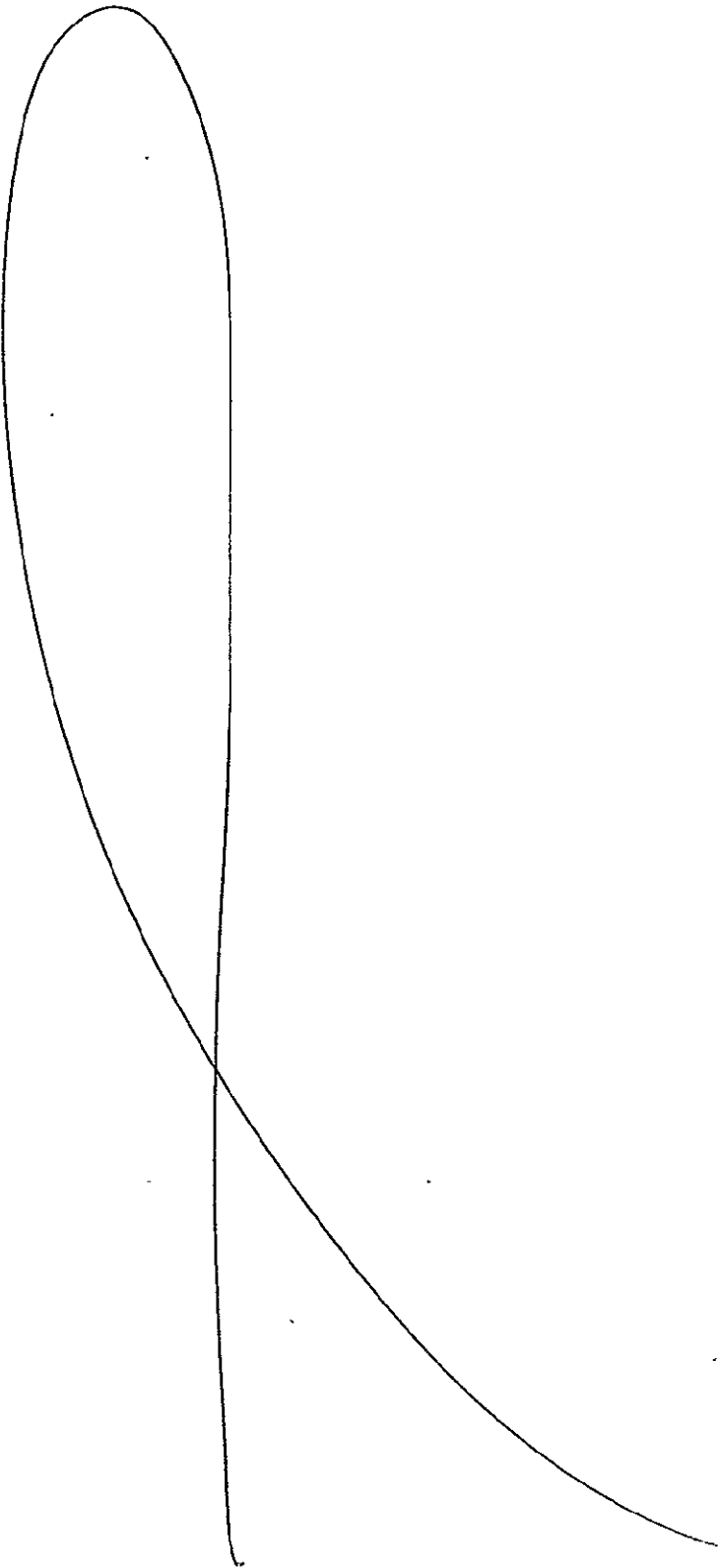
The environmental impacts are those associated with the increased exploration, production, transportation, processing, conversion, distribution, and end-use consumption of fossil fuels.

The political and social impacts are more difficult to assess. International politics may change if the U. S. decreases its reliance on foreign energy sources. Occupational and geographical shifts and of decreasing purchasing power in the presence of probable increases in energy industry profits may have severe social impacts. The interaction of big energy concerns with government in terms of influence on each other may have important political consequences. Along with electric utilities, big fossil fuel companies will probably induce a strong central government to deal with them. The implications of the latter are far-reaching and basically beyond the competence of this group to determine.

Deregulation of natural gas prices (or gradual increases in the interstate price ceilings) may occur in the near future. By causing energy prices to rise, it most likely will reduce their consumption. Higher relative prices may also induce substitution for scarce fuels. Coal itself and electricity from coal and nuclear fuels may replace oil and natural gas. Higher prices may finally cause consumers and producers to employ more efficient energy-using systems.

These conservation gains, as well as other good aspects of deregulation, must be weighed against the negative effects of higher prices. One might predict that high domestic prices of oil may lead to a policy of "drain America first-ism". This secondary impact of gas deregulation must also be considered before the final decision on it is made. At the present time, the U. S. Congress has been largely against the higher prices concomitant with deregulation. The Ford Administration favors the implications of conservation in deregulation. The debate is a heated one.

D-102.



## APPENDIX E. CONSERVATION AND THE INDUSTRY SECTOR

The industry task group has prepared a detailed background for chapter 5 which is presented in Appendix E. It is intended to present the detailed methodology used in the assessment of conservation in industry.

### E.1 INTRODUCTION

#### E.1.1 SYSTEM DIAGRAM

The Figure E.1.1-1 shows a representative system diagram for the purpose of organizing and displaying the task of assessing the conservation potential in industry. The first, second, third and fourth requirements are shown in Figures E.1.1-2, E.1.1-3, E.1.1-4 and E.1.1-5.

The process indicated in each diagram can be divided into four phases:

Phase I - The definition of the objective;

Phase II - The establishment of requirements;

Phase III - Determination of alternatives to the requirements;

Phase IV - Tradeoff analysis to determine the final result

#### E.1.2 CAPSULE DESCRIPTION

##### E.1.2.1 FOOD AND KINDRED PRODUCTS (SIC 20)

Food and Kindred Products is an industry characterized by diversity among its subcategories. The five food industries (listed below) selected by the EEA study, which was based on a study performed by the Conference Board for the Ford Foundation's Energy Policy Project, accounted for about 30% of the energy consumed by the entire food industry

##### Meat Packing

Output is expected to grow by 3.0% over the period 1975 to 1990. Energy consumption per unit of output will decrease at a rate of about 18% per year. Based on these projections net total energy consumption in meat packing will increase by roughly 2.8% per year. [EEA-74, 7-6]



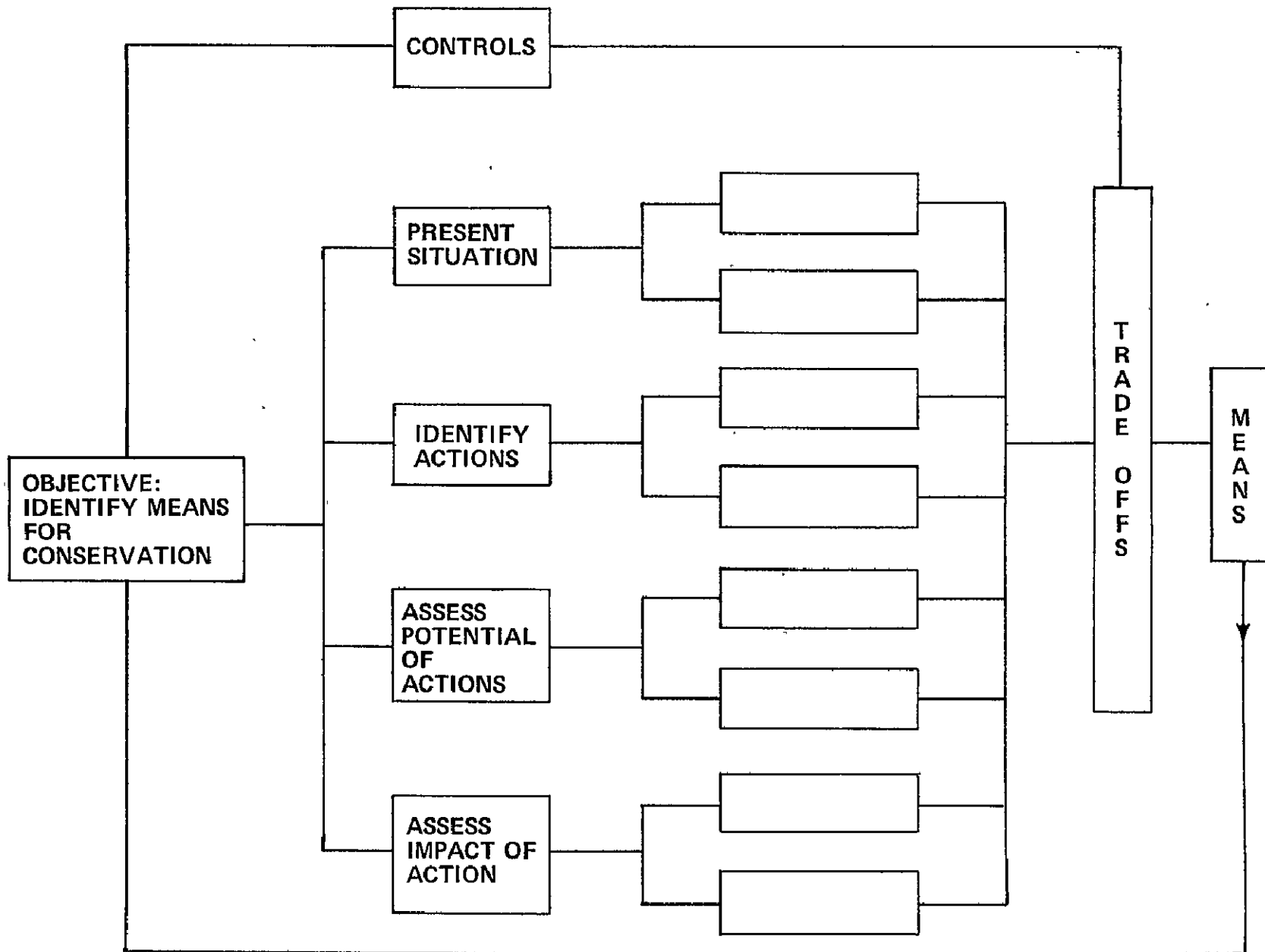


FIGURE E.1.1-1. SUB-STUDY OF REQUIREMENT 1.

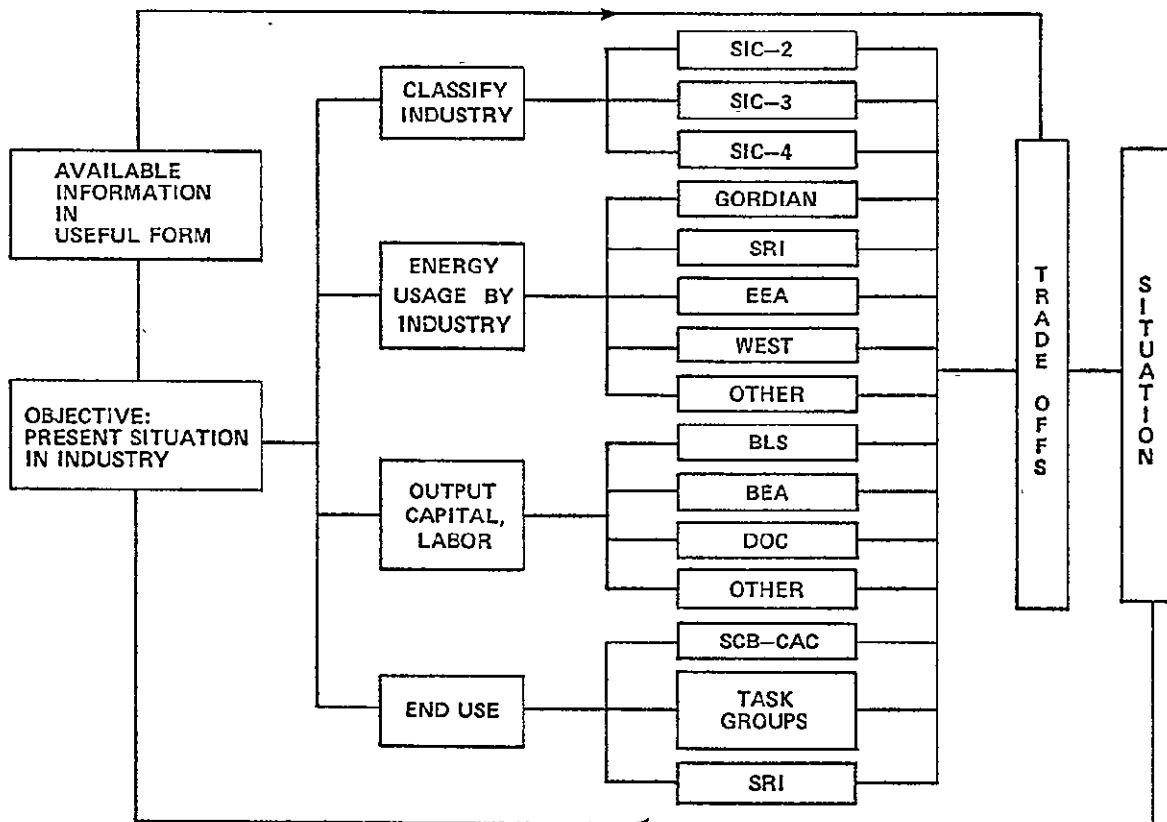


FIGURE E.1.1-2. SUB-SUB-SYSTEM OF REQUIREMENT 1

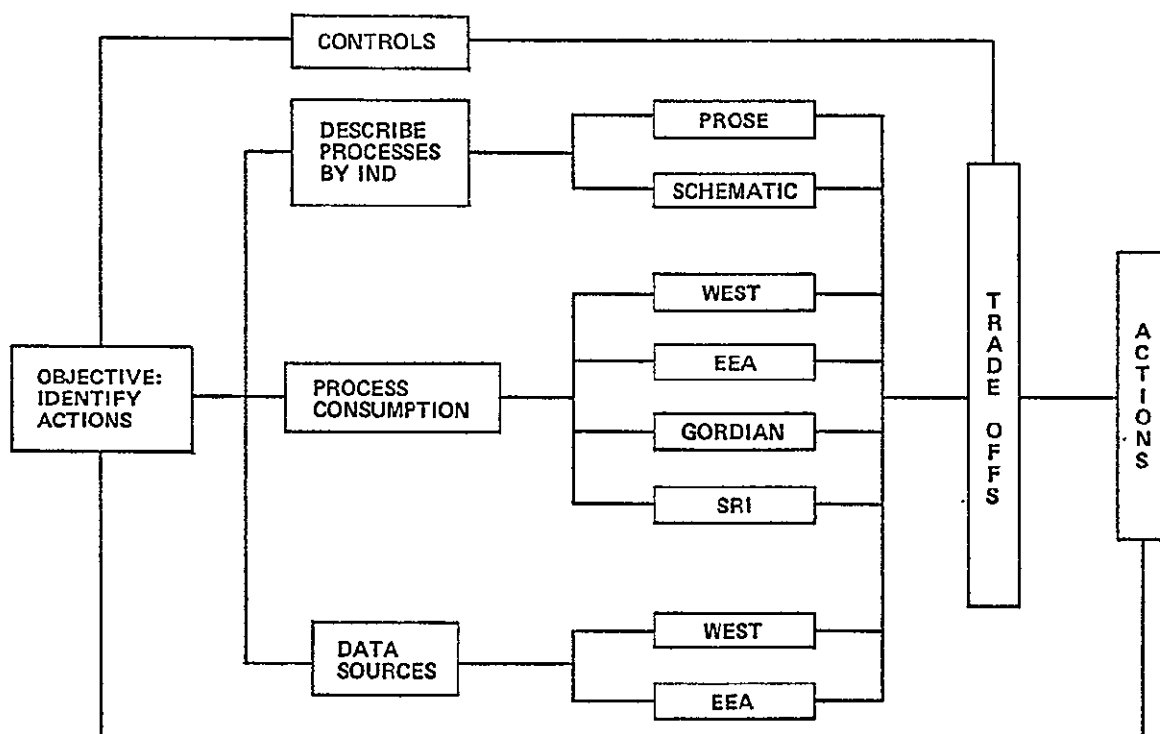


FIGURE E.1.1-3. SUB-SUB-SYSTEM OF REQUIREMENT 2

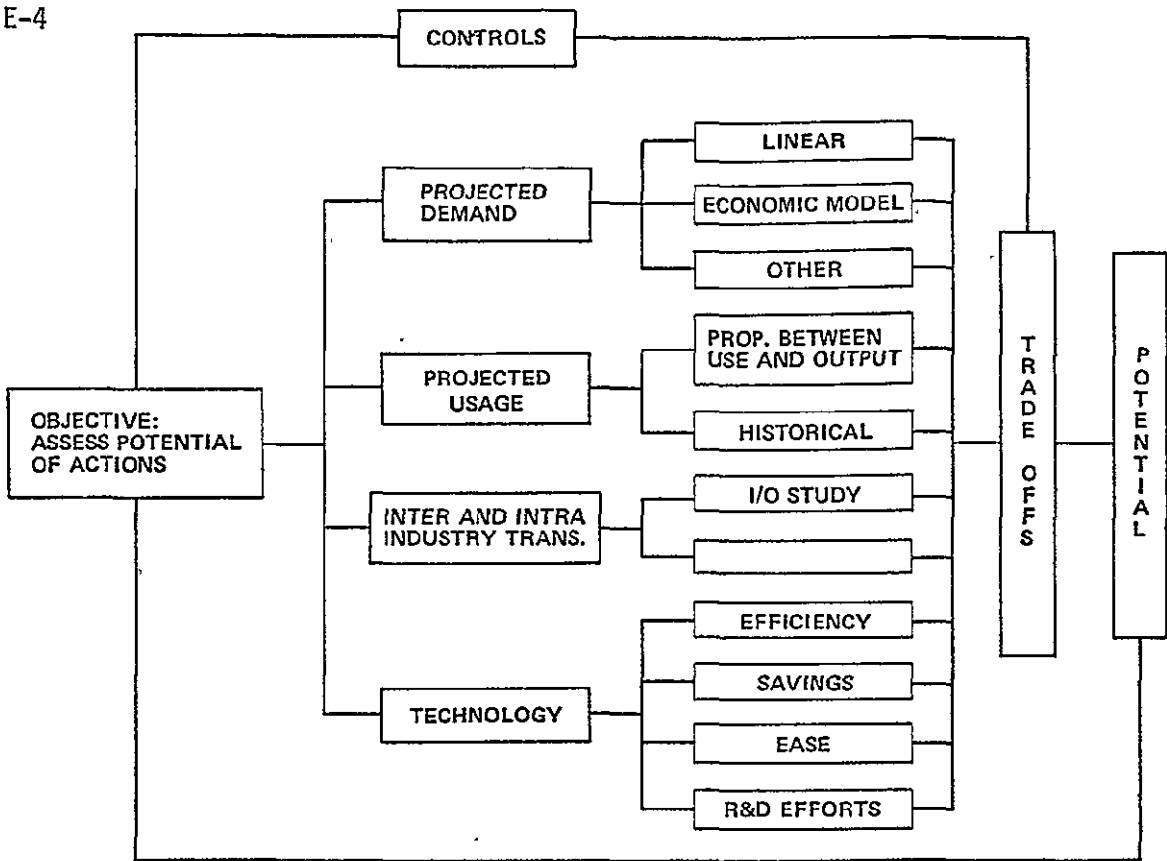


FIGURE E.1.1-4. SUB-SUB-SYSTEM STUDY OF REQUIREMENT 3

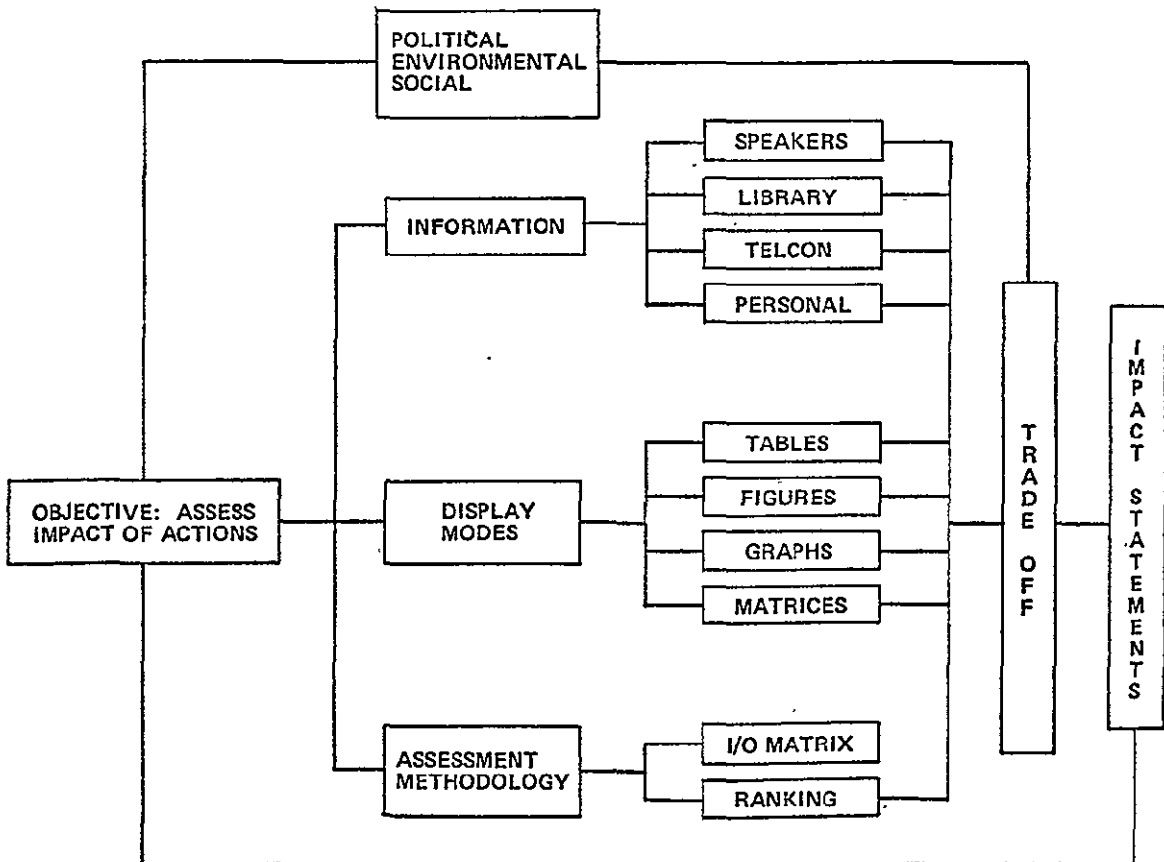


FIGURE E.1.1-5. SUB-SUB-SYSTEM OF REQUIREMENT 4

### Fluid Milk

Economies of scale associated with larger plants have resulted in the reduction of the number of fluid milk establishments by almost one-third with an accompanying reduction in energy requirements per unit of output.

A large drop in energy consumption per unit of output between 1954 and 1958 was the result of the switch from transport by cars to tanker trucks.

### Canned Fruit and Vegetables

The projected growth rate is about 1%/year. The energy input/output ratio is expected to remain constant after 1980.

### Frozen Fruits and Vegetables

Both production growth rates and energy consumption have been rising rapidly. The projected growth rates to 1990 is 7.0% per year. [EEA-74, 7-12]

### Bread and Other Bakery Products

Since 1954, the energy/output ratio has decreased steadily which is partly the result of a trend to softer breads and continuous baking processes and of major process innovations. From 1954 to 1967 the energy/output ratio dropped at a rate of 2.5%/year. [EEA-74, 7-15] The projected growth rate of energy consumption is 3.1% per year between 1975 and 1990. [EEA-74, 7-16]

## E.1.2.2 PAPER INDUSTRY (SIC 26)

Paper and paperboard are manufactured in two distinct steps: production of pulp, which is essentially a chemical process, and refining of pulp into paper or paperboard, which is essentially a mechanical process.

Some 85% of all pulping is done by chemical or semichemical means, and of the chemical processes, the alkaline sulphate or kraft process is the most commonly used and the most rapidly growing. Pulp is then refined into paper or paperboard to generate opacity and to improve strength and feel.

The pulp and paper industry generates two by-products that are used as fuel for the production of steam: bark and black liquor. Bark must be removed from the logs because of its low fiber value, and it is usually burned in bark boilers. Black liquor is the spent cooking liquor from the digester, a solution of inorganic chemicals (essentially sodium sulfide and caustic soda) and organic matter (lignin). The chemicals are recovered by evaporation, and the organic matter is burned in the recovery furnace producing thereby a substantial share of the mill's steam requirements.

### E.1.2.3 CHEMICAL AND ALLIED PRODUCTS INDUSTRY (SIC 28)

The Chemical and Allied Products Industry produce over 900 different chemical products including basic organic chemicals and synthetic organic intermediates. One measure of the chemical industry is that it furnishes many other industries with essential materials, basic inorganics and many finished products. The output of the chemical industry has been increasing rapidly; historical trends predict an increase in production index of 450% over the period of time from 1972 to 2000. Another measure of the importance of the chemical industry is that it was estimated to run a 5 billion dollar favorable balance of trade in 1974. [IO-75,90] Demand for chemical products is expected to remain strong. Dollar sales of chemical products are anticipated to increase more than 67% between 1974 and 1980 (\$11.9 billion to 20 billion).

### E.1.2.4 PETROLEUM INDUSTRY (SIC 29)

The petroleum industry is a highly complex multi-product industry employing numerous processes in series to convert crude oil into refined products.

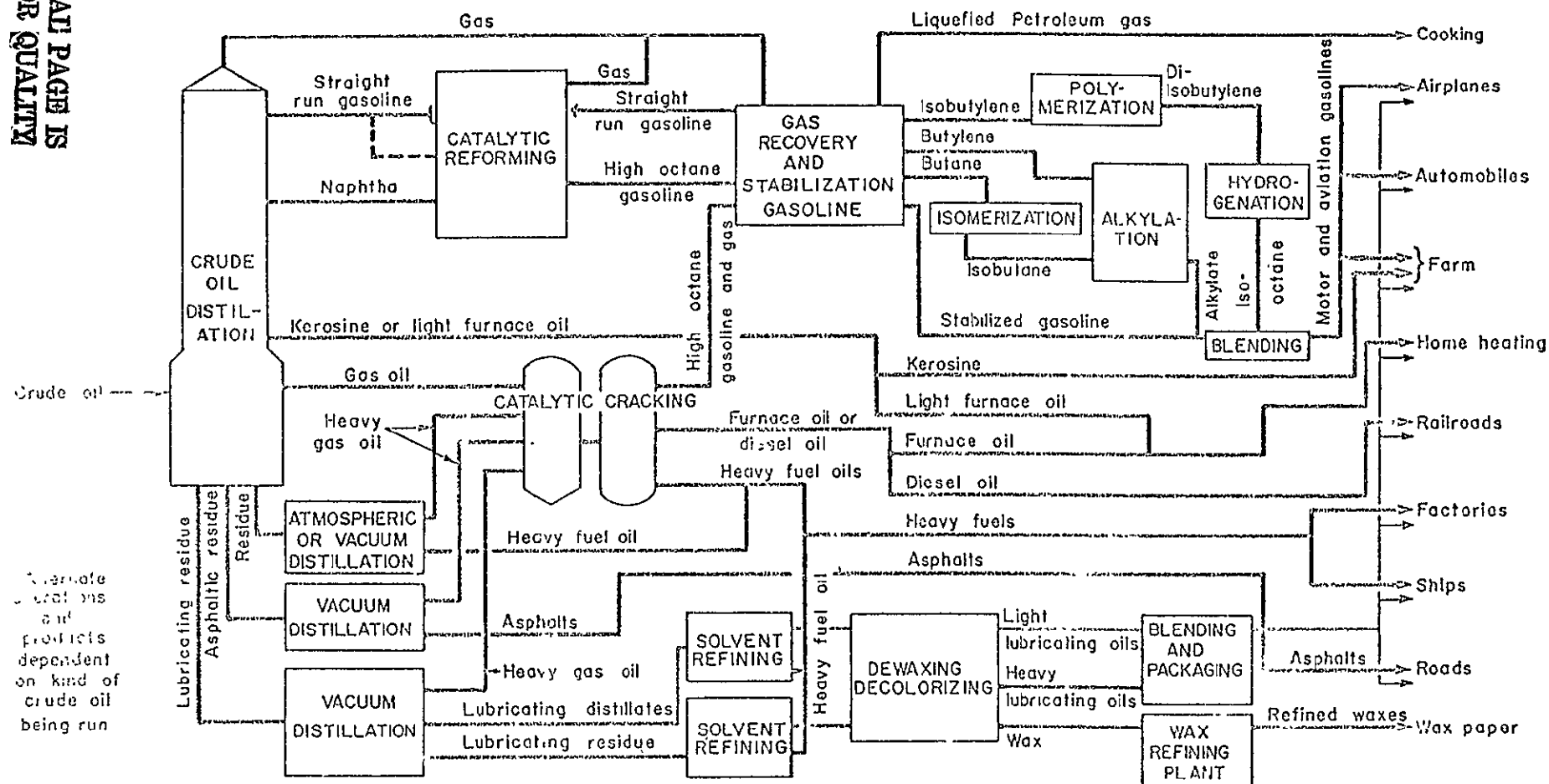
A generalized description of an overall refinery is shown in Figure E.1.2-1. Over the past 30 years, the refining industry has undergone rapid growth and significant technological change. The changes in technology have been aimed at increasing the yield of light petroleum products and improving product quality.

The rise in the domestic production of gasoline and distillate fuel oil at the expense of residual fuel led to the development of processes to convert heavy fractions into lighter products. These processes include thermal cracking and coking followed by catalytic cracking and hydrocracking. A typical refinery uses eight processes described in some detail by EEA [EEA-74]: crude distillation, vacuum distillation, coking, fluid catalytic cracking, catalytic reforming, alkylation, and naphtha and distillate hydrotreating.

Capacity and output of oil refineries has continued to grow despite a decrease in the total number of refineries in operation (see Table E.1.2-1) In 1960, 290 refineries were needed to produce 3,119 million barrels of oil. Thirteen years later (1973), 253 refineries processed 4,726 million barrels [P.I.T.F.R.L.-74, 82]. This significant increase in output with fewer refineries is largely the result of improved refining technology and larger and more highly automated facilities.

### E.1.2.5 STONE, CLAY, GLASS (SIC 32)

Hydraulic cement and glass containers are the major energy consumers in SIC 32.



E-7

TABLE E.1.2-1.

EMPLOYMENT AND OUTPUT OF PETROLEUM REFINERIES, 1960, 1965, AND 1968-73 [P.I.T.F.R.L.-74, 83]

YEAR	MANPOWER		PRODUCTION		Percent Change in Refinery Capacity	Number of Refineries	Output per All Employee Man-hour (1967=100)
	Employment	Percent Change <sup>1/</sup>	Output	Percent Change <sup>1/</sup>			
	(000's)		(millions of barrels)				
1960	177.2	-2.3	3119	1.6	1.0	290	62.7
1965	148.1	-1.0	3527	2.6	1.0	273	90.5
1968	150.1	1.5	4037	5.5	7.3	270	103.0
1969	144.7	-3.6	4149	2.8	3.6	264	107.0
1970	153.7	6.2	4252	2.4	2.6	262	107.6
1971	152.7	.7	4379	3.0	6.5	253	113.2
1972	150.8	-1.2	4593	4.9	3.0	250	125.7
1973	147.3	-2.3	4726	2.9	3.4	253	137.0

<sup>1/</sup> From previous year

Source: Bureau of Labor Statistics and Bureau of Mines

### Hydraulic Cement

The cement industry is relatively small, but very energy intensive and has great potential for energy savings. [PCA-74]

The production of cement involves the following principal operations:

Raw materials acquisition

Preparation of raw materials

Clinker production

Grinding and mixing of product cement

The acquisition of raw materials provides lime, silica, and alumina. The preparation of raw materials in the mixing of the materials is either wet or dry form. The key process is the calcining in a rotary kiln to produce clinkers. The final stage is the grinding of the clinkers into powder and the introduction of additives. A flow chart is shown in Figure E.1.2-2.

### Glass Containers

Between 1967 and 1972, output doubled. The main reason for growth was the substitution of non-returnable for returnable bottles. Non-returnable bottles captured over 85% of the drink market. Growth will slow considerably during the next few years as the replacement of returnable bottles with non-returnables reaches completion. [EEA-74]

The manufacturing of glass containers has three major energy consuming steps: (1) melting the raw materials, (2) refining the molten glass and (3) finishing. Melting accounts for roughly 75% of the total energy consumed, refining 5% and finishing 15%. The remaining 5% is consumed by auxiliary equipment.

#### E.1.2.6 PRIMARY METALS (SIC 33)

On a net energy consumption basis, primary metals industry accounted for approximately 28% of the total energy consumption within the industrial sector. The primary metals industry is composed of steel manufacturing, iron and steel foundries, smelting and refining of nonferrous metals, rolling and drawing and nonferrous foundries. Fabrication of metal products is excluded for this two-digit industry classification. This study focuses on steel and aluminum manufacturing as they account for 87% of the total energy consumption in primary metals. [EEA-74, I-67]



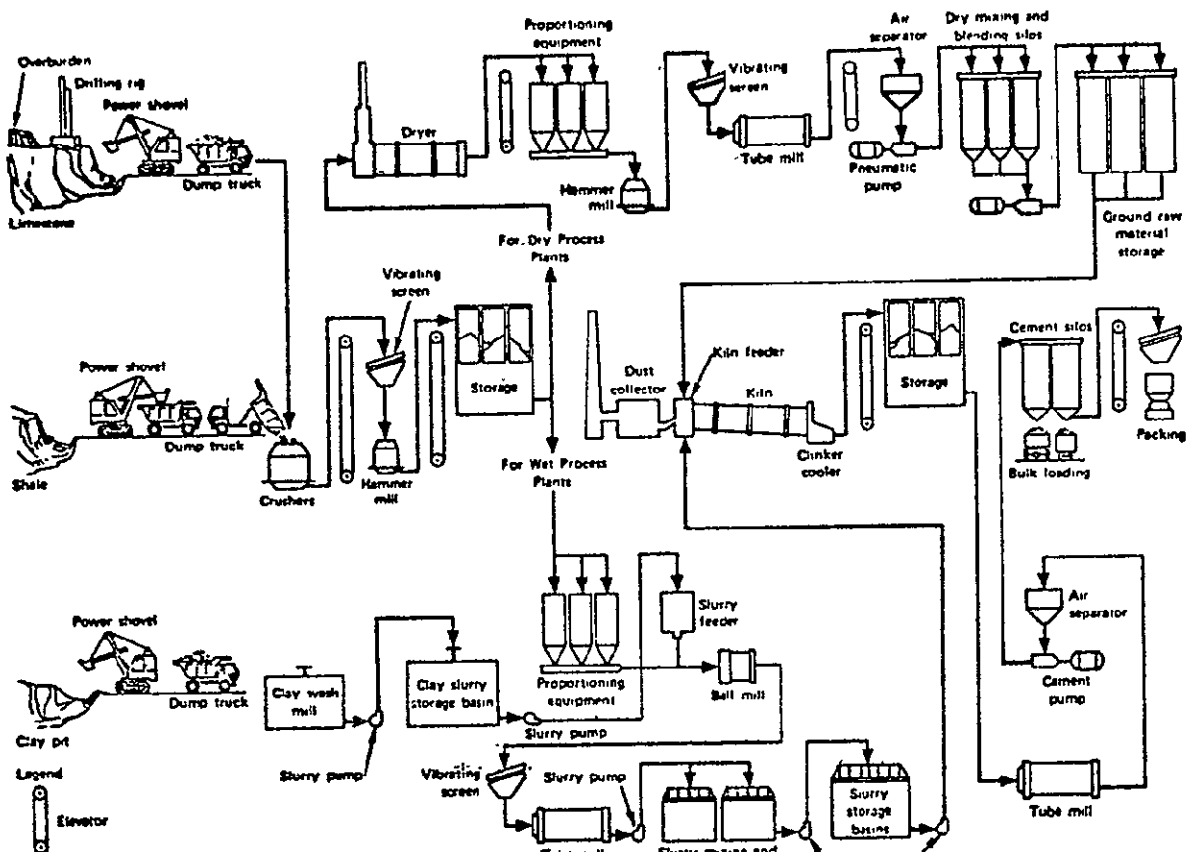


FIGURE E.1.2-2. SIMPLIFIED FLOW CHART FOR THE MANUFACTURE OF PORTLAND CEMENT [EEA-74]

ORIGINAL PAGE IS  
OF POOR QUALITY

## Steel

The production of steel involves mining, smelting and refining. The mining operation consists of open pit mining of the ore magnetite, hematite, and limonite, and subsequent beneficiation and agglomeration of the ore. The smelting process is the chemical reduction of the ore in the blast furnace to pigiron. An important part of the blast furnace charge is coke. Coke is formed by the retort method of heating crushed coal, removing the volatile products, and quenching the resultant coke. The refining of pigiron into steel involves the removal of carbon and other impurities by oxidation in a furnace. The refining process is identified by the type of furnace: the open hearth furnace, the basic oxygen furnace, the electric furnace. The semifinishing of steel is the production of ingots from molten steel. An important ancillary process in the refining stage is the production of oxygen from the oxidation process.

## Aluminum

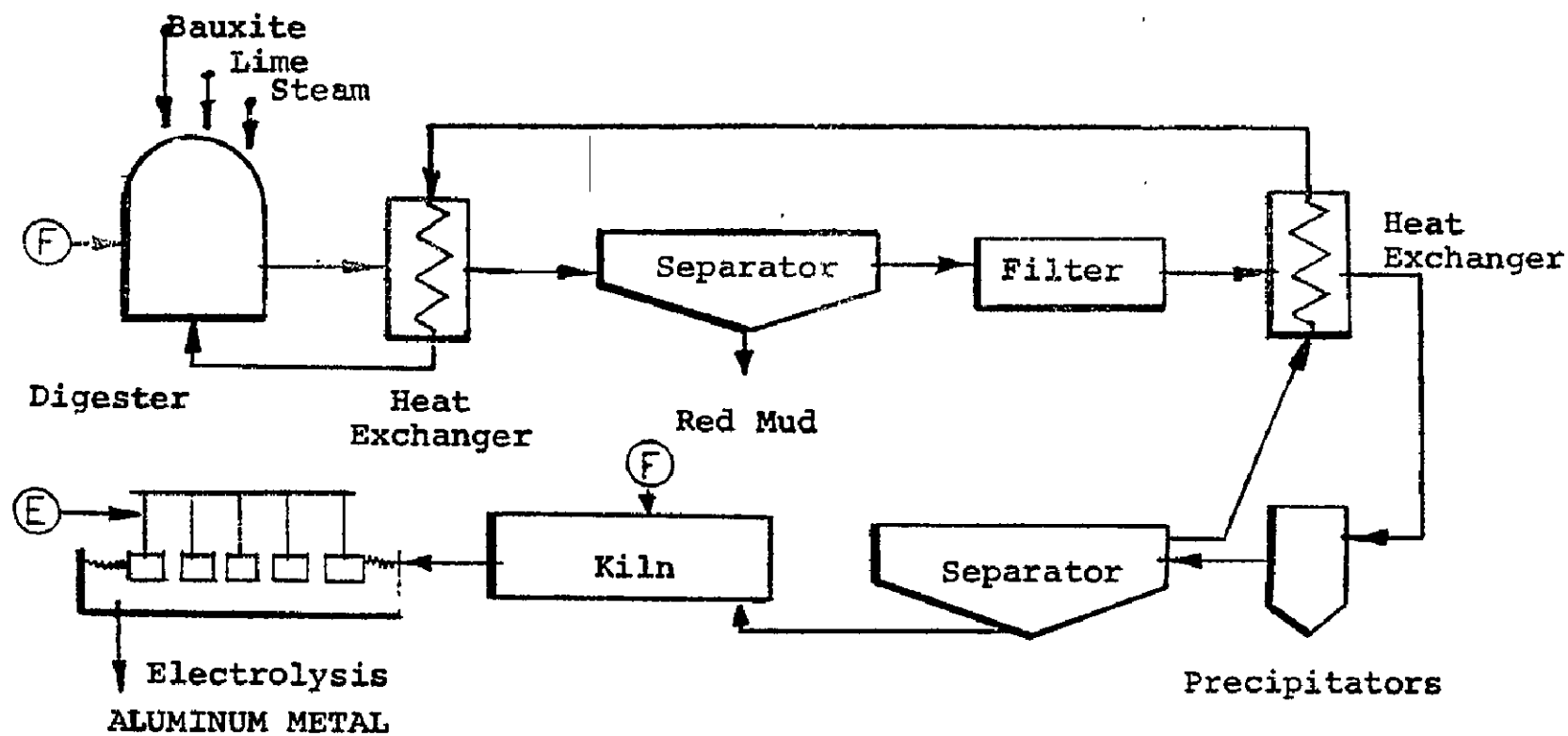
The production of aluminum consists of mining of bauxite, refining into alumina and smelting of alumina into aluminum.

The mining operation is the open pit extraction of hydrated alumina-bauxite. The Bayer process is used to refine bauxite. The refinement is digestion in caustic soda and removal of the insoluble components. The smelting of the alumina into aluminum is a reduction process by electrolysis -- the Hall-Heroult process. Figure E.1.2-3 diagrams the process.

## E.2 INDUSTRY ENERGY CONSERVATION

### E.2.1 FOOD AND KINDRED PRODUCTS (SIC-20)

As in other areas of the industrial sector, assessment of energy conservation in the agriculture and food processing area is difficult because of the diversity of the industry. In addition, the breakdown for energy consumption is difficult because there is no consensus of opinion as to the way energy usage should be charged to an industry. For example, according to the National Petroleum Council, agriculture and food processing energy usage is approximately 12% of the total U. S. industrial energy consumption, or approximately 3.2 quads annually. Energy consumption on the farm is about 30% of the total agriculture and food processing industries usage, or equivalent to about 1 quad annually. Food processing uses the remaining 2.2 quads. [NPC-75, 37] On the other hand, the EEA study assumes that food and kindred products account for only 5% of the total manufacturing energy consumption. [EEA-74, 7-2]



[ (E) = electrical energy input, (F) = fuel input ]

FIGURE E.1.2-3. BAYER-HALL ALUMINA TO ALUMINUM PROCESS  
[Prengle-75]

To add to the confusion or perhaps enlightenment, Dr. Bill Wortham has assumed that one should look at energy consumption in different terms. That is, input/output analysis was used to try to account for the amount of energy used in producing a particular product. The input/output model discussed in Appendix C is an even more comprehensive effort to analyze the consumption of energy used in producing various products and services. If the remaining products are grouped into logical consumption sets and if their energy is normalized by dividing by the 45.42% of the energy used in their production, Table E.2.1-1 shows the result.

Careful consideration of the above data may give a better understanding of why the U. S. consumes so much more per capita than other nations. Additional breakdown of the data showed that at least 40% of our food energy is invested in high protein foods. Probably no other nation expends this kind of energy in providing food.

A first cut examination of this data suggests that we as a nation might reduce our energy consumption by either changing our diets or becoming more efficient in the production of high protein food. [Wortham-75]

In this section we will be concerned with approaching energy consumption in the food sector in the traditional way. Food and Kindred Products is characterized by diversity among its subcategories in terms of historical and current energy/output coefficients, current and projected growth rates, and potential energy-saving technology. The industry in toto exhibits low growth rates and low energy consumption (see Figure E.2.1-1).

Fuels are primarily used for producing steam and hot water at temperatures below 400°F which is used in the various manufacturing processes and for providing space heat. Electricity is used for driving machinery, process equipment, and refrigeration equipment.

Total energy per unit of the production index has declined from  $9.17 \times 10^{12}$  BTU/index unit to  $8.61 \times 10^{12}$  BTU/index unit, and a further decline to  $7.85 \times 10^{12}$  BTU/index unit in the year 2000 has been projected. [West-75,C-4]

The use of coal has declined from 30% to 14% of the total while the use of gas has increased from 45% to 58%. Purchased electricity has increased from 8.5% to 12.2%. The use of electricity is expected to continue past trends and increase to 22.5% in the year 2000 due to increased processing requirements and some substitution of electric heating for fuel heating. Oil use is expected to decline to 15% and coal consumption is expected to be phased out by 1980. Gas consumption was calculated as the difference between total energy consumption and the contribution of coal, oil and electricity.

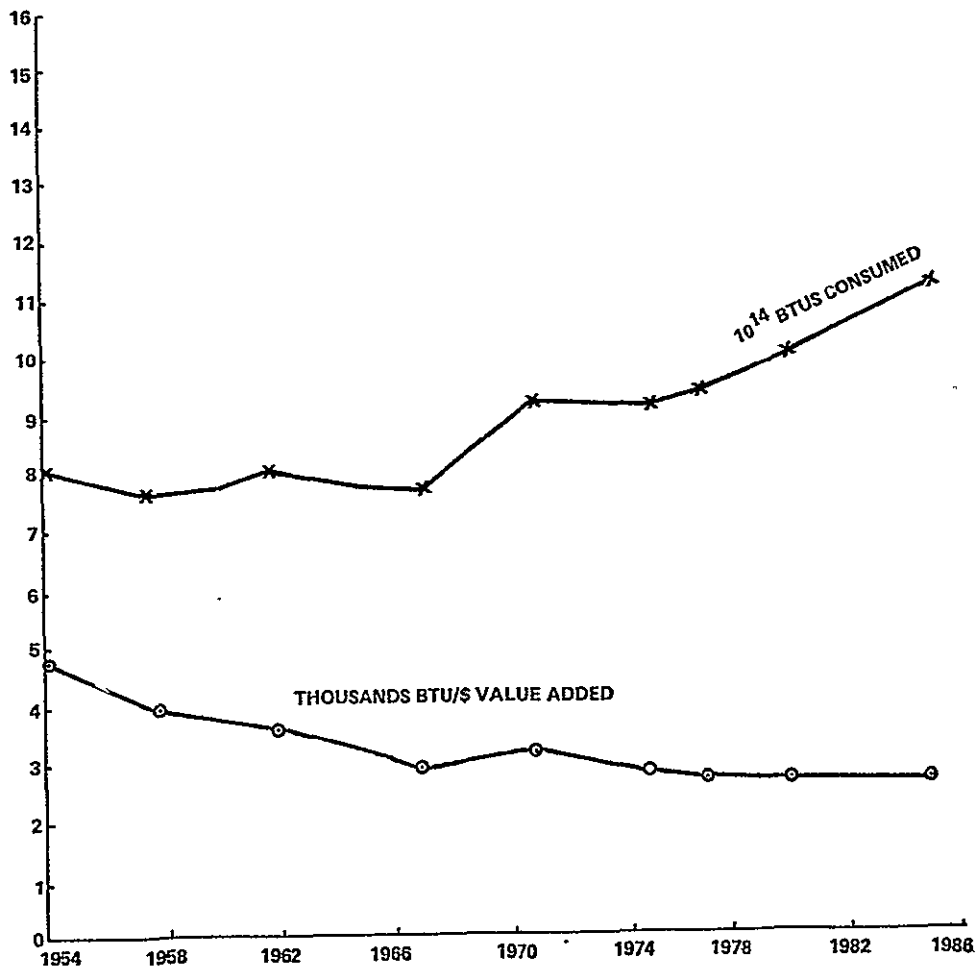
## E.2.2 CONSUMPTION STATUS PAPER

The Paper and Allied Products Industry consumed about 1.095 quads of energy in 1967 according to [SRI-72,124]. This figure is based on electricity at 3413 BTU/kWh. [EEA-74,I-23] gives 1967 energy consumption at about 2.20 quads. [EEA-74,2-3] gives 1971 energy consumption at 1.315 quads. This

TABLE E.2.1-1. CONSUMPTION SETS

E-14

Category	% of Delivered Energy
Food and Beverage	32
Transportation, Products and Services	16
Drugs and Service	14
Shelter	11
Clothing	9
Furniture and Appliances	6
Religious and Educational	4
Communications	2
Other	<u><u>6</u></u> <u>100</u>



ENERGY CONSUMPTION FOR FOOD & KINDRED PRODUCTS  
(DATA FROM EEA-74, 1-30)

FIGURE E.2.1-1.

comes to 31.98 MBTU/\$VA. Of this 1.315 quads, 1.196 quads was purchased fuels other than electricity. If the use of process waste is included, the figure for 1967 usage is about 2.08 quads. [PFE-74,59] The breakdown of the energy use according to this same report is (million BTU per ton of product):

Heat	19.5
Electricity (fuel equivalent)	5.0
Waste	14.5
Total	39.0

A different breakdown of fuel sources from the same report is:

Waste products	37%
Purchased fuels	50%
Purchased electricity	<u>13%</u> (10,000 BTU/kwh)
	100%

A breakdown of the end use of fuel by form and process is [PFE-74,61]:

Pulping (Steam)	58%
Paper Making (Steam)	17%
Pulping (Electricity)	20%
Paper Making (Electricity)	<u>5%</u>
	100%

### E.2.3 CHEMICAL INDUSTRY CONSUMPTION STATUS

The historic energy consumption pattern of the chemical industry is given in Table E.2.3-1. The chemical industry is a large energy user. Only petroleum refining and primary metals consumed more total energy than chemicals production in 1971. Because of the rapid growth anticipated for the industry, Table E.2.3-1 projects that by 1985, the chemical industry will be the largest energy user in the industrial sector. Because of this and because their industry supplies many intermediate products to other industries, energy conservation measures in the chemical industry should have far reaching effects. The majority of the energy consumed by the chemical industry was non-electric. Table E.2.3-1 shows that nearly 90% of the energy consumed in 1971 was direct fuel use. Over 70% of the fuel used was natural gas. [West-75,C-26]

TABLE E.2.3-1. HISTORICAL AND PROJECTED ENERGY REQUIREMENTS: 1954-1985 [10-75]

	1954	1958	1962	1967	1971	1975	1977	1980	1985
<b>Total Manufacturing (Trillion BTU)</b>	<b>9826</b>	<b>10698</b>	<b>12501</b>	<b>14765</b>	<b>15940</b>	<b>19092</b>	<b>20641</b>	<b>22211</b>	<b>25580</b>
Fuel (Trillion BTU)	9187	9836	11301	13315	14179	16838	18166	19401	22147
Electricity (Trillion BTU)	639	862	1200	1450	1761	2184	2475	2809	3432
Value Added (Billions 1967/\$VA)	139.8	153.29	192.03	261.98	301.56	390.66	441.68	505.72	611.06
Energy/Output (Thousand BTU/\$VA)	70.29	69.79	65.1	56.36	52.86	49.12	46.73	43.92	41.86
Fuel (Thousand BTU/\$VA)	65.72	64.16	58.86	50.82	47.02	43.1	43.13	38.36	36.24
Electricity (Thousand BTU/\$VA)	4.57	5.62	6.25	5.53	5.84	5.59	5.60	5.55	5.62
<b>Total Six High Energy Consuming Industries</b>	<b>8351</b>	<b>9210</b>	<b>10672</b>	<b>12385</b>	<b>13226</b>	<b>15554</b>	<b>16595</b>	<b>17554</b>	<b>19978</b>
Fuel (Trillion BTU)	7902	8577	9904	11393	12070	14081	15012	15772	17784
Electricity (Trillion BTU)	449	633	768	992	1156	1410	1583	1782	2196
Value Added (Billions 1967/\$VA)	51.66	59.02	72.20	93.66	101.91	130.49	144.18	163.42	199.16
Energy/Output (Thousand BTU/\$VA)	161.65	156.02	147.65	132.23	129.78	119.20	115.10	107.42	100.31
Fuel (Thousand BTU/\$VA)	152.96	145.3	137.02	121.64	118.41	107.9	104.12	96.51	89.30
Electricity (Thousand BTU/\$VA)	8.69	10.72	10.63	10.59	11.34	10.8	11.00	10.90	11.03
<b>Food &amp; Kindred Products (SIC20)</b>	<b>805</b>	<b>766</b>	<b>803</b>	<b>767</b>	<b>920</b>	<b>912</b>	<b>939</b>	<b>1001</b>	<b>1154</b>
Fuel (Trillion BTU)	764	712	738	684	800	806	830	885	1018
Electricity	41	54	65	83	120	106	109	116	136
Value Added (Billions 1967 \$)	16.96	19.66	22.44	26.62	28.77	32.95	34.80	38.08	43.86
Energy/Output (Thousands BTU/\$VA)	47.46	38.96	35.78	28.81	31.98	27.68	26.98	26.29	26.31
Fuel	45.05	36.22	32.89	25.69	27.8	24.46	23.85	23.24	23.21
Electricity	2.42	2.75	2.9	3.12	4.17	3.22	3.13	3.05	3.10
<b>Paper &amp; Allied Products (SIC26)</b>	<b>648</b>	<b>806</b>	<b>929</b>	<b>1156</b>	<b>1315</b>	<b>1276</b>	<b>1325</b>	<b>1415</b>	<b>1473</b>
Fuel (Trillions BTU)	611	763	871	1067	1196	1120	1166	1235	1250
Electricity	37	43	58	88	119	148	159	180	215
Value Added (Billions 1967 \$)	5140	6030	7460	9756	11356	13893	14897	16614	19697
Energy/Output (Thousands BTU/\$VA)	126.07	133.67	124.53	118.49	115.8	91.8	88.9	85.2	74.8
Fuel	118.87	125.53	116.76	109.37	105.32	81.2	78.27	74.33	63.87
Electricity	7.2	7.13	7.77	9.02	10.48	10.65	10.67	10.83	10.92
<b>Chemical &amp; Allied Products (SIC28)</b>	<b>1359</b>	<b>1634</b>	<b>1969</b>	<b>2598</b>	<b>2783</b>	<b>3757</b>	<b>4428</b>	<b>4822</b>	<b>6175</b>
Fuel	1201	1342	1661	2272	2443	3301	3864	4180	5293
Electricity	158	292	308	326	340	456	564	642	882
Value Added	8.47	11.30	15.78	23.55	29.08	40.31	47.78	57.39	76.68
Energy/Output	160.44	144.6	124.78	110.32	95.7	93.2	92.7	84.02	80.5
Fuel	141.79	118.76	105.25	96.48	84.0	81.9	80.9	72.8	69.0
Electricity	18.7	25.04	19.52	13.84	11.7	11.3	11.8	11.2	11.5
<b>Petroleum &amp; Coal Products (SIC28)</b>	<b>1761</b>	<b>2020</b>	<b>2316</b>	<b>2556</b>	<b>2956</b>	<b>3359</b>	<b>3409</b>	<b>3507</b>	<b>3869</b>
Fuel	1741	1990	2275	2502	2877	3268	3324	3412	3759
Electricity	20	30	41	54	79	91	85	95	110
Value Added	3190	3710	4440	5420	6559	8121	8555	9233	10340
Energy/Output	552.04	544.47	521.62	471.59	451	413.6	398.0	380	374
Fuel	545.77	536.39	512.39	461.62	439	402.4	308	370	364
Electricity	6.27	8.09	9.23	9.96	12	11.2	10	10	10.6
<b>Stone, Clay, &amp; Glass Products (SIC32)</b>	<b>905</b>	<b>945</b>	<b>1056</b>	<b>1229</b>	<b>1367</b>	<b>1440</b>	<b>1530</b>	<b>1647</b>	<b>1700</b>
Fuel	874	904	1003	1162	1291	1338	1417	1517	1649
Electricity	31	41	53	67	76	102	113	130	139
Value Added	5130	5890	6940	8333	9325	10641	11716	13099	15316
Energy/Output	176.41	160.44	152.16	147.49	146.6	135.3	130.6	125.7	116.7
Fuel	170.37	153.48	144.52	139.45	138.4	125.7	120.9	115.8	107.7
Electricity	6.04	6.96	7.64	8.04	8.2	9.6	9.6	9.9	9.1
<b>Primary Metals Industry (SIC33)</b>	<b>2873</b>	<b>3049</b>	<b>3599</b>	<b>4080</b>	<b>4030</b>	<b>4810</b>	<b>4964</b>	<b>5162</b>	<b>5519</b>
Fuel	2711	2876	3356	3706	3673	4304.2	4410.9	4543.3	4805.4
Electricity	162	173	243	374	417	505.8	553.1	618.7	713.6
Value Added	12.77	12.44	15.22	19.98	18.95	24.58	26.42	29.01	33.26
Energy/Output	224.98	245.1	236.47	204.2	212.6	195.7	187.9	177.9	165.9
Fuel	212.29	231.2	220.5	185.49	190.6	175.1	167.0	156.6	144.4
Electricity	12.69	13.91	15.97	18.72	20.0	20.6	20.9	21.3	21.5
<b>Energy Consumed by All Other Manufacturing</b>	<b>1475</b>	<b>1488</b>	<b>1829</b>	<b>2300</b>	<b>2714</b>	<b>3538</b>	<b>4046</b>	<b>4657</b>	<b>5602</b>
Fuel	1285	1259	1397	1922	2109	2757.8	3154	3629	4365
Electricity	190	229	432	458	605	780	892	1027	1236
Value Added	88.14	94.26	119.75	168.32	199.05	260.17	297.5	342.4	411.9
Energy/Output	16.73	15.79	16.1	14.1	13.6	13.6	13.6	13.6	13.6
Fuel	14.58	13.36	11.7	11.4	10.6	10.6	10.6	10.6	10.6
Electricity	2.16	2.42	3.6	2.72	3.0	3.0	3.0	3.0	3.0

## E.2.4 PETROLEUM REFINING (SIC 29)

### Energy Consumption Status

Although the complexity of U. S. refineries has increased, energy consumption per barrel of output has remained fairly constant. Figure E.2.4-1 shows the growth in refined product output and the historical energy/output ratios. On a volumetric basis output grew at roughly 3.6% per year from 1947 to 1971, but currently energy consumption per barrel of output is almost the same as in 1947. In value terms, output has grown at 4.4% per year, with energy consumption per dollar of output declining by .7% per year. [EEA-74, 4-10]

There are two major reasons for the observed stable energy/output ratio which has been maintained over the last twenty-five years in spite of substantial increases in refinery complexity. One reason has been the gradual replacement of energy intensive thermal processes by catalytic processes. Thermal cracking, for example, requires almost 250 times as much energy per barrel of throughput as does fluid catalytic cracking. [EEA-74, 4-11]

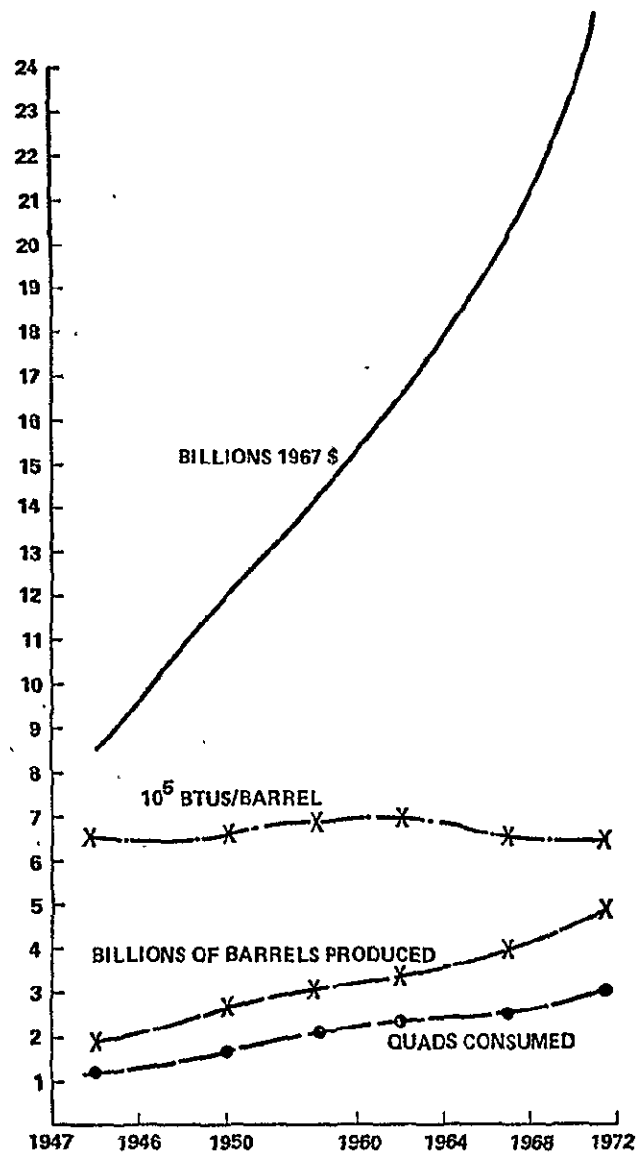
A second reason for industry's ability to maintain its historical energy/output ratio has been the continual refinement and improvement of standard refining techniques. As the science of petroleum refining has matured, improved process design and control as well as increased integration of refining operations have helped to reduce energy consumption and, on a per unit operation basis, the consumption of energy has decreased.

Three factors have been identified as likely to determine future energy consumption levels in the refining industry: (1) the degree of emphasis placed on conservation efforts; (2) domestic policy towards imported finished products and crude oil; and (3) future product specifications. The EEA study assumes that combining non-capital and capital intensive energy conservation measures can result in a savings of 15% from 1971 consumption. [EEA-74, 4-29] This study also assumes that the effect of domestic petroleum import policy on process energy requirements will be neutral. The third factor - future product specification - is extremely important since there is a direct relationship between product quality and energy consumption. Each of these areas was discussed at some length in the EEA report.

Energy is used in the refining process in three ways: (1) the raising of steam; (2) direct process heat, and (3) electricity for pumps and motors.

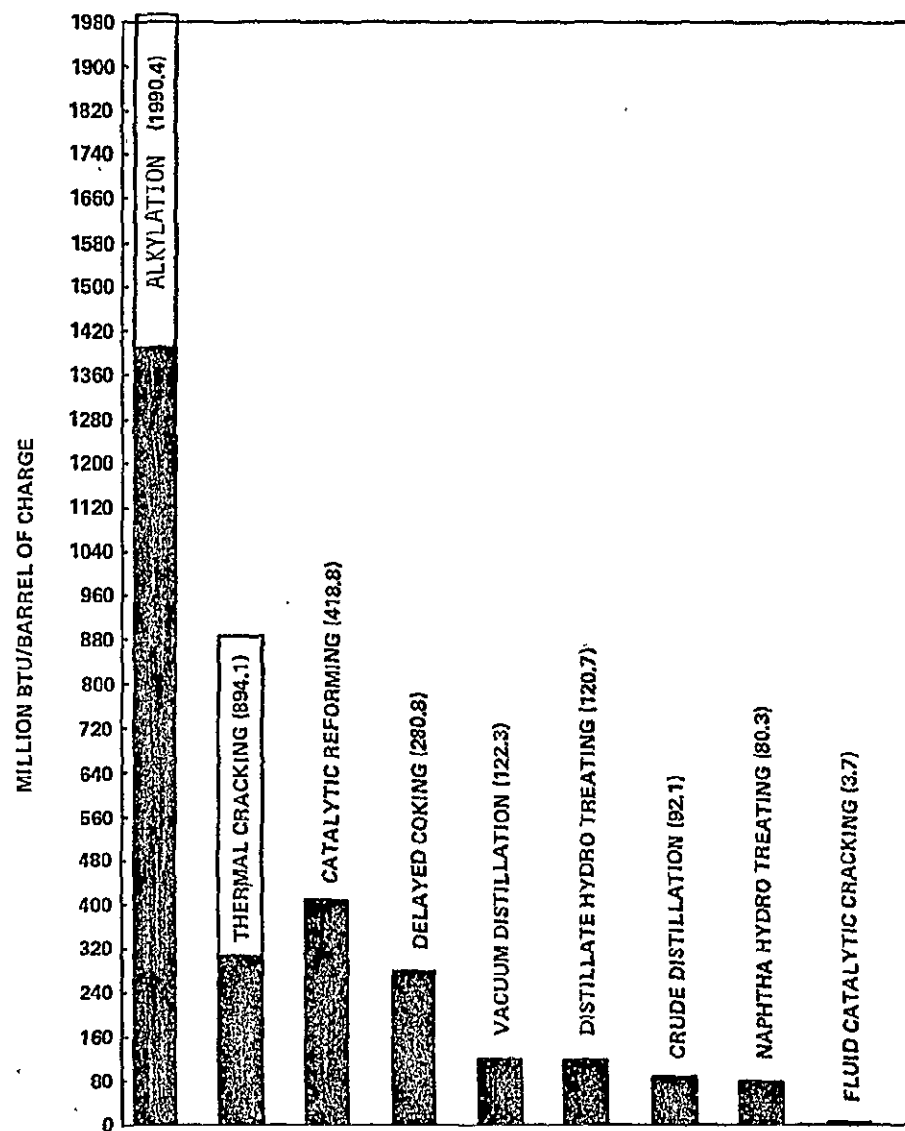
As can be seen by the bar graph in Figure E.2.4-2, the most energy consumptive processes are alkylation and thermal cracking (obsolete) followed by catalytic reforming and coking. Alkylation and catalytic reforming have been growing as a percent of crude capacity. This trend will probably continue because both processes can be used to produce high octane unleaded gasoline, which will become increasingly important in the future as the use of tetraethyl lead is reduced. [EEA-74, 4-12]





REFINING PRODUCTION LEVELS AND HISTORICAL ENERGY/OUTPUT  
COEFFICIENT (BASED ON EEA DATA, EEA-74, 4-11)

FIGURE E.2.4-1.



ENERGY REQUIREMENTS FOR REFINING PROCESSES

FIGURE E.2.4-2.

[EEA-74]

A comparison of the three areas of energy requirements for a simplified representative refinery are shown in Table E.2.4-1. According to the EEA study, direct process heat requirements account for 78% of total energy usage, followed by electricity at 12% and steam raising at 10%. On the other hand, the Prengle study [Prengle-75, 4-9] and the Stanford Research Institute Report [SRI-75,] indicate a different breakdown of these percentages. The fact that Prengle's study is limited to refineries in Texas could explain the discrepancies in the data.

However, the wide variation in data may simply be a result of the diversity of the industry and the assumptions made by the various assessing groups as to the requirements for a typical refinery. This is indicative of the difficulty involved in trying to assess the potential for conservation in industries as complex as the refining industry.

#### E.2.5 STONE, CLAY AND GLASS CONSUMPTION STATUS

The historic energy consumption pattern is shown in Table E.2.3-1. The industry has some flexibility and there are possibilities for substitution of fuel.

#### E.2.6 PRIMARY METALS

The historic energy consumption pattern is shown in Table E.2.3-1. The primary metals industry is the largest consumer in the manufacturers sector.

#### E.2.7 ENERGY CONSUMPTION - BY ENERGY SOURCE

Table E.2.7-1 displays the source of energy purchased by six manufacturing industries for 1967. Data are from [CAC-75].

#### E.2.8 ENERGY CONSUMPTION -- AN ALTERNATIVE MEASURE

In assessing energy consumption, attention has focused on the total BTU's each industry purchases. Industry uses this energy to produce its total output which is divided into sales to intermediate and final markets. All production, either directly or indirectly, goes to satisfy final demands. This suggests that an alternative measure of energy consumption of an industry would be the direct energy plus the indirect energy needed to meet its final sales. Indirect energy is the energy required to produce the intermediate products an industry consumes. For example, steel is an intermediate product used in automobile manufacturing. The energy required to produce that steel would be charged to the automobile industry. The advantage of this accounting scheme is that it captures immediately the direct and indirect effects of a change in final sales. If consumers demanded -- or were required to buy -- smaller automobiles, the direct impact on the economy would be a shift in the size composition of vehicles.

TABLE E.2.4-1. DISTRIBUTION OF ENERGY IN A REFINERY

	% of Total Consumed		
	<u>Prengle-75*</u>	<u>EEA-74</u>	<u>SRI-75</u>
Direct Process Heat	60	78	60
Steam Generation	25	10	34
Electricity Generation	15	12	6

\*Prengle's study is confined to refinery operations in Texas

TABLE E.2.7-1. PURCHASED ENERGY [CAC-75]

	COAL	REFINED PETRO- LEUM	ELECTRIC UTILITIES	NATURAL GAS UTILITIES	TOTAL
SIC 26 Paper & Allied Products	$3.6 \times 10^{14}$	$3.1 \times 10^{14}$	$8.8 \times 10^{13}$	$4.0 \times 10^{14}$	$1.2 \times 10^{15}$
SIC 20 Food & Kindred Products	$2.0 \times 10^{14}$	$2.0 \times 10^{14}$	$9.2 \times 10^{13}$	$4.5 \times 10^{14}$	$9.2 \times 10^{14}$
SIC 28 Chemical & Allied Prod.	$2.5 \times 10^{14}$	$4.9 \times 10^{14}$	$3.3 \times 10^{14}$	$1.9 \times 10^{15}$	$2.9 \times 10^{15}$
SIC 29 Petroleum Refining	$4.3 \times 10^{13}$	$1.9 \times 10^{15}$	$5.4 \times 10^{13}$	$9.9 \times 10^{14}$	$2.9 \times 10^{15}$
SIC 32 Stone, Clay, Glass	$3.2 \times 10^{14}$	$1.3 \times 10^{14}$	$6.7 \times 10^{13}$	$7.0 \times 10^{14}$	$1.2 \times 10^{15}$
SIC 33 Primary Metals	$2.5 \times 10^{15}$	$2.9 \times 10^{14}$	$3.7 \times 10^{14}$	$1.3 \times 10^{15}$	$4.4 \times 10^{15}$

If smaller units required less steel the impact would be a less energy intensive automobile. Note, however, that an indirect reduction in the demand for steel may have negative impacts on the steel industry. Whatever the eventual repercussions, the initial impact was on the transportation industry, not on the steel industry.

Which industries sell most of their output to final markets? The ratio of final demand to total output for 13 industry groups is given below:

Food and kindred products	.73
Textiles and Textile Products	.47
Lumber and Wood Products	.34
Paper and Allied Products	.19
Chemicals and Allied Products	.30
Petroleum Refining	.48
Rubber and Rubber Products	.37
Stone, Clay, Glass	.08
Primary Metals	.05
Fabricated Metal Products	.12
Machinery	.56
Electrical Machinery	.53
Transportation	.67

Notice that Primary Metals, Stone, Clay and Glass, Paper and Allied Products, and Chemicals sell a majority of their output to intermediate markets. Under the accounting scheme discussed above, it is unlikely these industries will remain the targets of conservation opportunity.

The energy cost per dollar of final demand can be computed using the direct requirements matrix of the input-output display. It is possible that an industry has a low BTU/dollar of final product but a large impact on total BTU's. Such an industry is Food and Kindred Products. Most of that industry's output goes directly to final markets. It happens that its final market is the largest of all the industry groups considered. Thus, the potential impact depends on energy per unit of final demand and for the size of the final demand.

Assuming such an energy accounting method was adopted, the relative importance (in terms of energy consumption) of the 13 industries changes. The rankings are given in Table E.2.8-1. The far right column

TABLE E.2.8-1. ENERGY COST (DIRECT AND INDIRECT) PER DOLLAR OF FINAL DEMAND  
(1967)

INDUSTRY	BTU/\$ OF FINAL DEMAND (1967) DIRECT & INDIRECT $\times 10^5$	TOTAL BTU FOR FINAL DEMAND DIRECT & INDIRECT $\times 10^{15}$
Food and Kindred Products	.71	5.04
Textiles	.68	1.50
Lumber	.70	.51
Paper & Allied Products	.91	.78
Chem & Allied Products	2.21	3.09
Petroleum Refining	10.82	13.93
Rubber	.83	.59
Stone, Clay, Glass	1.58	.09
Primary Metals	2.57	.63
Fabricated Metal Prod.	1.09	.51
Machinery	.77	2.37
Electric Machinery	.82	.89
Transportation	.80	3.96

ranks the industries by energy purchased directly. The calculations of the energy cost come from an aggregated I-0 model constructed for this report. While this model was constructed only for illustrations, the numbers compare favorably with estimates published in [CAC-74].

The energy costs per dollar of final demand are given in Table E.2.8-2 refining (and gas utilities). The relative rankings change.

### E.3 CONSERVATION STATUS

#### E.3.1 INTRODUCTION

This section discusses the current status of conservation and the conservation potential in the six most energy intensive industries. Tables E.3.1-1, E.3.1-2 and E.3.1-3 from the Ford report give estimated energy uses under their three scenarios for industry as a whole. [Ford-74]

Industrial end-use energy consumption accounted for about 23.1 quads in 1972. The major conservation opportunities in the industrial sector include: [PI-74,171]

- modifying equipment to improve efficiency,

- adjusting combustion controls and cleaning heat exchange surfaces in furnaces,

- utilizing waste heat, and

- utilizing solid wastes.

#### E.3.2 FOOD INDUSTRY

##### E.3.2.1 AGRICULTURE

According to the National Petroleum Council's report [NPC-74, 37], short-range conservation can be achieved best through intensive educational and training programs. The major difficulty is the problem involved in supplying information to the millions of individual farmers. (There are some 2.8 million farms in the United States.) The general procedures to do this exist, however, and many actions have already been initiated through federal and state agricultural agencies and extension services, universities and agricultural associations. In the short term, only 2% savings per unit of output is anticipated. [NPC-75, 38]

Over the longer term, the following are areas where possible increased energy efficiencies may be obtained.

- Development of more efficient and better yielding crops

TABLE E.2.8-2. INDUSTRY RANKING ACCORDING TO THE ENERGY COST OF FINAL DEMANDS

INDUSTRY	BTU/\$ <sup>a</sup> FINAL DEMAND (DIRECT & INDIRECT)	TOTAL BTU FOR FINAL DEMAND	TOTAL BTU PURCHASED
Food & Kindred Products	11	2	4
Textiles	13	6	
Lumber	12	12	
Paper & Allied Products	6	8	5
Chem & Allied Products	3	4	2
Petroleum Refining	1	1	3
Rubber	7	10	7
Stone, Clay, Glass	4	13	6
Primary Metals	2	9	1
Fabricated Metal Prod.	5	11	
Machinery	10	5	
Electrical Machinery	8	7	
Transportation	9	3	

a) CAC-74

TABLE E.3.1-1. PROJECTED INDUSTRIAL ENERGY USE [Ford-74]

	1973	1985	2000
Historical Growth	29.5	52.1	96.9
Technical Fix	29.5	40.0	63.1
Zero Energy Growth	29.5	37.9	47.0

TABLE E.3.1-2. POTENTIAL ENERGY SAVINGS IN THE INDUSTRIAL SECTOR (Quadrillion BTU's) [Ford-74]

Technical Fix vs. Historical Growth			
	1985	2000	
Industrial energy use in HG scenario	46	87	
Potential Savings	Conservation Measures		
Five energy intensive industries	4.3	13.1	More efficient production processes in paper, steel, aluminum, plastics and cement manufacture.
Miscellaneous process steam	0.5	3.5	Onsite industrial cogeneration of steam and electricity.
Miscellaneous direct heat	2.9	5.4	Use of heat recuperators and regenerators with direct use of fuels instead of electric resistive heat.
Other	2.5	7.4	
Total savings	10.2	29.4	
Industrial energy use in TF scenario	36	58	

Note: Only the manufacturing sector's share of energy processing losses is included above.

TABLE E.3.1-3. POTENTIAL ENERGY SAVINGS IN THE INDUSTRIAL SECTOR (Quadrillion BTU's) [Ford-74]

Zero Energy Growth vs. Technical Fix			
	1985	2000	
Industrial energy use in TF scenario	36	58	
Potential Savings	Conservation Measures		
Aluminum	0.2	0.3	Ban aluminum cans
	-	0.3	Recycle 75% of available old scrap (compared to 50% in TF)
Steel	0.4	1.0	Reduce growth in steel output from 2.5 to 1.5% per year
Plastics	1.5	4.7	Reduce growth in plastics output (to 2.7% per year for 1985-2000)
Other	-	8.4	General shift in industrial mix to less energy intensive activities
Total savings	2.1	14.7	
Industrial energy use in ZEG scenario	34	43	

Note: Only the manufacturing sector's share of energy processing losses are included here.



Optimization of the use of chemical fertilizers with maximum use of manure and farm by-products for fertilizer

Use of "no tillage" or minimum tillage for land preparation and crops where practical

Development of crops that are more resistant to insects, disease and birds, thus reducing energy inputs of pesticides and other chemicals

Production of specific crops only in regions that give maximum yields per unit of energy input

Use of natural field drying to the maximum extent possible

#### E.3.2.2 FOOD PROCESSING

Over three-fourths of the food produced by agriculture is commercially processed before its final use. Significant energy savings in the food processing industry which are possible include:

Utilization of wastes and by-products instead of disposal (e.g., nutshells, fruit pits)

Less packaging of foods with more bulk handling

Education of consumers in energy efficient foods.

#### E.3.2.3 COOKING/STERILIZATION AND REFRIGERATION

A major limitation to energy conservation in the food processing industry is the need to assure the safety of humans and animals. Cooking/sterilization and refrigeration are two high-energy consumption steps in food processing. An estimated 15 to 20 percent, and 20 to 25 percent, respectively, of total food processing energy is used in each of these processes. Adequacy of the operation is a must to provide nutritious and safe products. Practically all food products contain large amounts of moisture and are thus subject to spoilage. Many cooked/sterilized products must be canned or kept refrigerated. Increased energy efficiency opportunities exist in these operations. The operations themselves cannot be omitted under current economic and technical conditions. Improvements in food handling and processing equipment operations are the most promising for short-range energy conservation.

Of all the food industries, frozen foods and vegetables are the most technologically innovative with a great variety of production processes. Product improvement has been the motivating force for technological innovations, i.e., some new processes consume more energy than those they replace. In general, it is not the product being frozen that determines energy consumption but the method and volume of products frozen.

Considerations of product quality have led the industry to replace "sharp freezing" with "quick freezing" of which there are several types. This switch brought a sharp rise in energy consumption to operate fans and other equipment. One quick freezing variant, multiple plate freezers, used relatively little energy but failed to takeover the industry because of the large labor costs involved.

The latest innovation has been the use of cryogenic freezing with liquid nitrogen or other low temperature requirements. In terms of both product quality and greatly reduced energy costs this is the best method. However, at present, costs are prohibitive since the cost of nitrogen alone for one year often equals the entire investment in another type of freezing equipment. If the cost of nitrogen drops drastically, which is not expected, energy costs for the industry would also decline radically.

Practically all food processing industries have enlarged their energy conservation programs. An overall energy savings rate of 5 percent per unit of output, based on year 1972, was achieved by the end of year 1973. An additional 5 percent savings per unit of output should be realized by the end of year 1974. These savings have required minimal processing changes and capital investment. [NPC-75, 38]

There are further opportunities for significant short-term energy use reductions. In total, savings of 10 to 15 percent per unit of output are expected by 1978. Most of these savings require revised processing techniques, energy recovery systems, processing controls, and even some different food products. Most require capital expenditures. [NPC-75, 38]

### E.3.3 PAPER INDUSTRY

The Paper and Allied Products Industry consumed 1.095 quads\* of energy in 1967 [SRI-72-124], or 11,670 BTU per pound of product. This unit figure represents a 15 per cent reduction since 1958. If the use of process waste is included, the figure for 1967 usage is about 2.08 quads. [PRE-74,59] Several trends and developments that have been observed through 1967 are as follows: [SRI-72,124-126]

"Increased use of the sulphate (draft) pulping process, which is -- generally -- a less energy consuming process than other pulping processes.

Increased use of continuous digesters instead of batch digesters. Kamyr continuous digesters are estimated by the manufacturer to reduce the steam requirement of cooking by 40% and that of evaporation by 15% to 20%.

\* Electricity converted to BTUs at 3413 BTU per kWh

Decreased use of waste paper from 0.28 pounds per pound of paper and paperboard production in 1958 to 0.21 pounds per pound of paper and paperboard production in 1967 and a resulting increase in wood pulp use from 0.73 pounds per pound to 0.78 pounds per pound. Since pulp made from recycled waste paper uses only about one-fourth of the steam energy and less than one-tenth of the electric energy than that made from wood, declining use of waste paper results in increased energy consumption per unit of finished product.

Pulp yields increased from 96% in 1958 to 98% in 1967, resulting in decreased energy consumption per unit of finished product.

Increasing use of chips from the lumber and wood products industry.

The trend toward more refined products, with larger per unit energy consumption, increased the average energy consumed.

Increased emphasis on pollutant removal from water and air released from pulp and paper mills tends to increase energy consumption."

Another report, [EEA-74,I-33] gives 1967 energy consumption in the paper industry at about 2.20 quads. This report estimates that housekeeping measures will reduce energy needs by 16 percent between 1971 and 1990. Improved processes are estimated to result in a 10% energy use reduction by 1990. The use of larger integrated mills is estimated to yield a 7 1/2 percent energy savings by 1990. The cumulative effect of these conservation measures is estimated [EEA-74,I-36] to be a reduction to  $27 \times 10^6$  BTU/Ton in 1990 from  $40 \times 10^6$  BTU/Ton. [PI-74-3,2-20] The figures for 1985 are:  $28.4 \times 10^6$  BTU/Ton [EEA-74,I-36] and  $34.8 \times 10^6$  BTU/Ton [PI-74-3,2-20].

The usage of energy in the Paper Industry was up to 2.6 quads in 1972 [PI-74-3,2-3] This report projects that energy use per dollar of value added will decrease by 2.26 percent per year through 1980 for a total decrease of 18.6 percent compared to the 1971 figure. This reduction will be due primarily to an increased use of residual fuels produced during the production process and better controls over process heat requirements. In a different section of the report, it is estimated that purchased energy requirements per ton of finished product will be reduced 17-23 percent between 1972 and 1990. [PI-74-3,2-1]

Actions that can be taken by the Paper Industry to conserve energy can be grouped as follows: [PI-74-3,2-12]

Housekeeping measures

Capital improvements

New, more energy efficient capacity, and

Alternate fuels

According to [NPC-74,43] a potential savings of 15 percent per unit of output is projected in the paper industry by 1978, and many companies have reported achieving savings of 10-12 percent in purchased energy per unit of output since October, 1973.

#### E.3.4 CHEMICAL INDUSTRY

Historically, the chemical industry has a record of achieving substantial reductions in energy usage (a 31% decrease in energy use per unit of product in the 17 years from 1954 to 1971). [West-75, C-25] These reductions resulted in large part from the two following facts: (1) the energy situation has and will continue to exert a large influence on the costs, prices, and product availability of the chemical industry [IO-75,90] and (2) the chemical industry has typically expended 3 percent of sales for R&D [IO-75,94] versus an all industry average of close to 2%.

It is not surprising then, that further large decreases in energy usage per unit of output are anticipated for the chemical industry. Prengle [PRE-74, 3-5] in his analysis of 226 chemical plants in Texas projects a potential saving of 31.1% of energy per unit of output over the next 6 1/2 years. Table E.3.4-1 shows current and possible energy usages. It is important to note that the largest improvements are anticipated in the combustion processes. It is also valuable to observe that these estimations do not include all types of major process redesign and other advanced technology such as improved selectivity catalysts. Energy reductions for these types of technology improvements are generally believed to be large but not well known. Projecting the Prengle estimate to the entire chemical industry appears reasonable since almost 56% of that industry's energy consumption occurs in Texas. [PRE-74,25] [IEC-75,11]. Also Prengle's data was obtained from chemical company estimates.

The chemical industry has entered into a voluntary program with the FEA to reduce energy use per unit of output 15% by 1980 (1972 base). [IEC-75,11] Table E.3.4-1 shows the historical energy usage reduction per unit of output, the voluntary commitment and the Prengle projection. It is apparent that the voluntary commitment does not represent a major departure from historical energy percentage reduction per unit of output. Indeed, the industry voluntary commitment is actually somewhat lower since it does not include energy needed to meet OSHA and Environmental requirements.

Capital requirements for the energy conservation achievement given by Prengle (and projected to the entire U. S. chemical industry) are \$0.58 billion over a 6 1/2 year period. The total projected capital spending for the U. S. chemical industry in 1975 alone is 5.3 billion.

TABLE E.3.4-1. ENERGY CONSERVATION POTENTIAL [PRE-74,5-22]

	% of total energy used	estimated savings % (1985)*
I. Combustion		
A. Heater Efficiency	92	
Capital Investments		16.8
Improved Operation		1.0
B. Process Improvements		
Capital		5.
Good Housekeeping		7.5
II. Electricity (purchased for mechanical drives)	7.5	
Capital Investments		.72
Good Housekeeping		0.03
III. Steam (process heat)	<u>.5</u>	<u>      </u>
TOTALS	100	31.1

\*Only 6 1/2 years required for implementation

Total Capital Required for Conservation  
\$323 x 10<sup>6</sup> 1975 dollars

1974 Texas SEC =  $16 \times 10^6 \frac{\text{BTU}}{\text{Ton Product}}$  (SEC means specific energy consumption, BTU/Ton)

1985 Texas SEC =  $11.8 \times 10^6 \frac{\text{BTU}}{\text{Ton}}$

1974 Texas Production  $81 \times 10^6$  Tons/yr.

1974 Texas Energy Consumption  $1.30 \times 10^{15}$  BTU/yr

1974 Total U. S. Chemical Industry Energy Consumption  $2.32 \times 10^{15} \frac{\text{BTU}}{\text{yr.}}$

% of Chemical Industry Energy Consumed in Texas =  $\frac{1.30 \times 10^{15}}{2.32 \times 10^{15}} \times 100 = 56\%$

### E.3.5 REFINING

It has been estimated that better maintenance and improved systems control overall could result in a 5% reduction in energy usage. Surveys of major oil companies indicate that programs resulting in savings of this magnitude are already underway. [EEA-74, 4-29]

An additional 10-15% savings is believed to be possible by implementing various conservation actions [discussed in Section E.5] requiring capital expenditure. However, it appears to be the general feeling in industry that energy conservation measures which involve capital improvements should be treated the same as any other capital outlay. That is, investment should take place up to the point where the rate of return is equal to the opportunity cost of alternative investment projects.

Unlike some other industries such as steel and cement, the processes which are currently in use in refining will probably continue to be the dominant processes of the future. The refining industry has already been replacing energy intensive processes in cases where the economics favored a less energy intensive process. Thermal cracking, for example, requires almost 250 times as much energy per barrel of throughput as does fluid catalytic cracking. Indicative of the relative desirability of fluid catalytic cracking, thermal cracking has dropped from 36% of refining capacity in 1945 to only 2% in 1972 [EEA-74, 4-12].

It is unlikely that higher energy prices will force refineries to retire large processing units much more rapidly than they would have in the absence of higher prices. The development of improved catalytic processes which in the past has led to significant energy savings will continue, but no major breakthroughs are anticipated at this time.

Therefore, in most cases the relevant economic considerations relate to retrofitting existing equipment with energy saving devices, improving maintenance and operating procedures, or constructing new refineries with these energy saving devices built in. Major capital projects are discussed in the EEA study [EEA-74, 4-22].

In the future, refineries will probably be designed with energy conservation in mind. Whether or not these refineries will be designed to minimize energy consumption will depend on the economics of the situation. Minimizing energy consumption is not necessarily synonymous with maximization of profits. The configuration of refineries coming on line during the next twenty years will be determined by future demand for petroleum products and the prevailing market prices for these products.

Exxon made a comprehensive survey of their refineries in 1971. They found that on average their refineries were consuming approximately 33% more energy than required at high efficiency levels of operation. According to Exxon the high efficiency consumption rate is applicable to new modern refineries, but the refineries built 10-15 years ago are not operating at these levels.

Exxon believes that new refineries will achieve high levels of efficiency resulting in consumption of approximately 40% less energy per barrel than the current U. S. average. With regard to existing plants they believe that higher energy prices have created sufficient incentive to reduce energy usage by 15% from medium efficiency levels. In Exxon's case this would result in a savings of roughly 100 MBTU per barrel. If all U. S. refineries could achieve this improved level of efficiency it would reduce average U. S. refinery consumption from its current average of 648 MBTU/barrel to 446 MBTU/barrel -- a savings of over 30 percent [EEA-74, 4-13].

Projecting energy requirements for the refining industry is extremely difficult. There are a number of very important variables, such as the composition of crude oils and the future octane quality of gasoline, which are difficult to forecast accurately. Table E.3.5-1 provides one projection of future refining energy requirements. It is based on a number of assumptions:

- Short term non-capital intensive housekeeping efforts will reduce energy requirements by five percent per unit of output;

- Longer term capital improvements, e.g., air preheaters, optimization of heat exchangers on existing plants, will ultimately reduce energy consumption by an additional ten percent;

- New refineries coming on line between 1975 and 1990 will be operated at a relatively high level of efficiency, consuming 430,000 BTU per barrel of output;

- The changing composition of crude oil processed in U. S. refineries and the mandatory reduction of lead additives in gasoline will have a neutral effect on refinery energy consumption;

- The U. S. will adopt an import policy which discriminates against imported refined product, but will continue to import residual fuel oil from Caribbean refineries.

The net result of these assumptions is that energy consumption per barrel of refined product will steadily decrease throughout the period. Over the period 1971 to 1980, energy consumption drops 97 MBTU per barrel. Conservation efforts in old refineries are responsible for 75% of the decrease, and new, more efficient refineries are responsible for the remainder.

With regard to projecting energy requirements for new refineries, it has been assumed that they will achieve the high levels of efficiency estimated by Exxon. This assumption may be somewhat conservative given the degree of emphasis presently being placed on energy consumption within the refining industry. However, energy consumption rates in this range would represent a significant improvement over current levels of efficiency.

TABLE E.3.5-1. PROJECTED ENERGY REQUIREMENT [EEA-74,4-39]

Year	Existing Plants			New Plants		Energy Impact			
	Existing Capacity (MMBD)	Conservation (Cumulative improve)	Net Energy Output (MBTU/B)	Net Additions (MMBD)	Energy/Output (MBTU/B)	Weighted Average (MBTU/B)	Fuel	Electric (10 <sup>12</sup> BTU)	Total
1958	8.2	-	660	-		660	1990	30	2020
1962	9.2	-	674	-		674	2275	41	2316
1967	10.6	-	641	-		641	2502	54	2556
1971	12.4	-	616	-		616	2798	75	2873
1975	14.5	7	573	.84	430	567	3181	80	3267
1977	14.5	10	555	1.59	430	546	3228	80	3308
1980	14.5	15	531	2.82	430	519	3305	89	3394
1985	14.5	15	531	4.72	430	508	3632	103	3735



Between 1980 and 1985 the rate of decline in energy consumption tails off; decreasing only by 12.0 MBTU per barrel during the period. Over the entire period 1971-1985, energy consumption per barrel of refined product decreases by 18%. Conservation measures account for 55% of the decrease and new refineries 45%. These measures will save approximately 395 thousand barrels of oil per day by 1990. [EEA-74, 4-40]. Figures E.3.5-1 and E.3.5-2 illustrate the magnitude of the savings obtainable if these conservation efforts are successful.

### E.3.6 STONE, CLAY, GLASS

Present conditions in the whole industry show that hydraulic cement and glass account for 45.6% of the energy requirements. [EEA-74,5-1]

#### E.3.6.1 CEMENT

Present conditions in the cement industry make an attractive environment for energy considerations. The industry is characterized by high energy usage, growing market expansion (sellers market) and technical flexibility. The conservation areas with the greatest potential are:

- conversion to dry kilns
- improvements in existing kilns
- conversion to high sulphur coal
- increased use of low energy materials

The conversion to dry kilns has a potential for large savings (a factor of 3 from worst to best). [EEA-74,5-9] The major obstacles are raw material limitations and economics of change. [GA-74-258]

Improvements in existing kilns include improved combustion efficiency, additional heat recovery and improved insulation materials. Additional changes in process could add savings without severe rate of return considerations. [EEA-74,5-16] The list includes more efficient grinders, process control and heat exchange systems.

The conversion to coal may not result in a savings of energy but will account for flexibility by the act of substitution. The major consideration is the industry's ability to consume high sulphur coal without undue environmental penalties as the process absorbs the sulphur. [PCA-74-43]

The increase in the use of non-energy intensive materials (pozzolanas) can have a potential energy savings of 20%. [Faber-75]

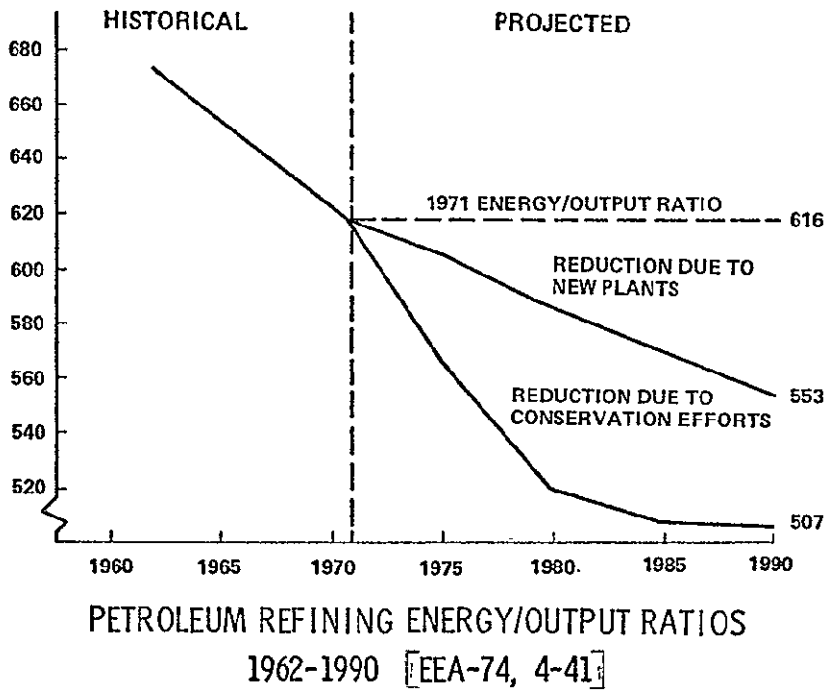


FIGURE E.3.5-1.

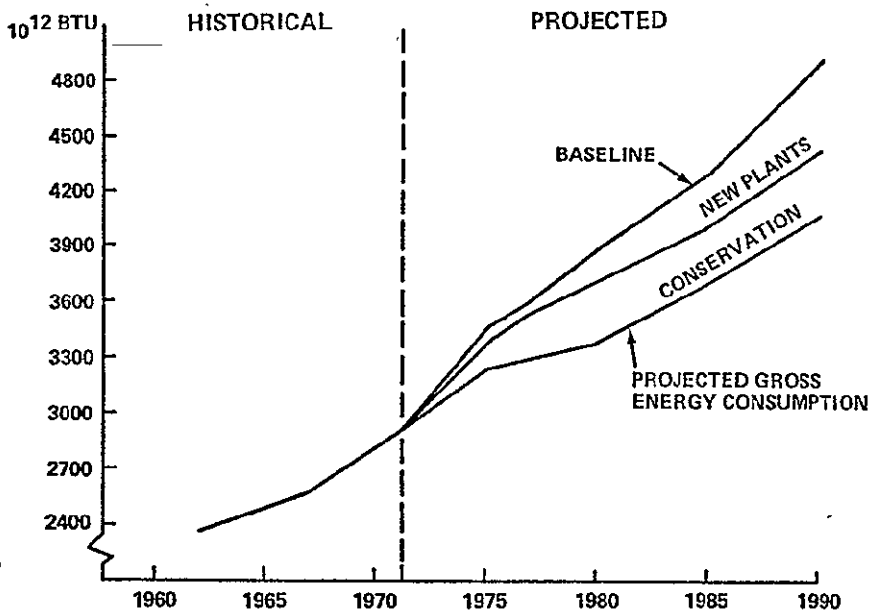


FIGURE E.3.5-2.

### E.3.6.2 GLASS

With the switch to disposable glass containers, the potential for reducing energy consumption per unit production during the next few years is not favorable. [EEA-74,I63] However, the areas with the greatest potential savings are:

- use of natural soda ashes -- 20% savings

- increase recycling -- 3% savings

- increase furnace efficiency

- material substitution

The area that causes the greatest problem in energy reduction is the conversion from natural gas to coal. Table E.3.6-1 gives a comparison among the various production techniques. It is noted that submerged combustion gives a substantial reduction, but there is concern that this technique will destroy the lining of the furnace.

Material substitution by increased use of plastic and larger size containers may have the largest short term impact. These factors may reduce the growth rate to zero by 1980. [EEA-74,I61]

### E.3.7 PRIMARY METALS

#### E.3.7.1 STEEL

The steel industry is optimistic about growth potential which will make possible the change-over to energy saving equipment and processes. [Gray-74]

The areas of conservation potential are:

- importation of ore

- reduction of coke use

- shifts in furnace technology

- new technology

The importation of ore will be the result of depletion of high grade U. S. ores. Importation has a favorable effect on U. S. energy consumption.

The 10% reduction in the ratio of coke to pigiron has occurred in the last 10 years. [GA-74-339] This practice is accompanied by increased use of other hydrocarbon fuels and oxygen.

TABLE E.3.6-1.  
 PRODUCTION TECHNIQUES AND ENERGY REQUIREMENTS [EEA-74-I63]  
 (MMBTU/ton)

	<u>Fuels</u>	<u>Electricity</u>	<u>Total Net Energy</u>	<u>Gross Energy</u>
Existing Fuel-Fired	6.8	-	6.8	6.8
Fuel-Fired with Boosting	4.8	1.3	6.1	8.8
Fuel-Fired with Oxygen Enrichment	6.3	-	6.3	6.3
All-Electric	-	2.9	2.9	8.9
Fuel-Fired with Submerged Combustion	4.1	-	4.1	4.1

The shift in furnace technology is from the open hearth to the basic oxygen furnace and the electric furnace. The shift will provide flexibility in heat cycle, hot metal charge, and primary fuel.

New technology is being developed in the areas of ore beneficiation of iron ores, blast furnaces, coke production, and furnaces.

#### E.3.7.2 ALUMINUM

In the short term there are limited conservation possibilities. The most promising is the change in production of electrodes.

In the long term there are two areas which show promise:

new refining process -- 30% savings

recycling -- 80% savings

The new refining process is being developed by Alcoa. It makes use of aluminum chloride which is easier to electrolyze. This reduces the electricity input by 30%.

Secondary aluminum production by recycling is related directly to progress in recovery techniques in solid waste streams. It is limited by reduction in demand, shift to other materials and substitution of waste for fossil fuels.

#### E.3.8 POTENTIAL CONTRIBUTIONS OF RESEARCH AND DEVELOPMENT TO INDUSTRIAL ENERGY-CONSERVATION

The potential for contributions of research and development (R&D) to industrial energy conservation is generally believed to be quite large. Many studies agree that energy savings as large as 20-25% (per unit of output) are possible through developing such technology as introducing more efficient machinery, developing alternate (low energy) processes, etc. However, there are many difficulties in implementing such work because: (1) Energy conservation has not been a "classical" area of industrial research. Hence, there will be difficulties because of unfamiliarity. (2) Energy has been a relatively inexpensive commodity and many R&D approaches to energy usage reduction which are now economically justifiable may still be considered impractical. (3) Industry is fragmented and research and development results which have potential for any one industry are difficult to recognize. (4) Private industry may be less interested in conducting and implementing energy conservation R&D since it will not directly reap many of the indirect benefits of so doing; e.g., benefits derived from reduced U. S. trade deficit.

Against this background of difficulties the assumption persists that research and development can substantially accelerate energy conservation.

In a presentation given to the ASEE Design Group it was noted that large increases in energy conservation in petroleum refining and chemical manufacture would result from R&D in process control and combustion technology. [PRE-75,1]

Based on the previous discussion, the questions which appear most important are: What R&D tasks should be undertaken? How can the results best be implemented? What is the future of the large body of already existing sophisticated technology in the U. S. which may be transferable (a form of research) to energy conservation?

At this point, it will be of benefit to make a distinction between R&D results and programs which can be used in the short term (implemented within 1 to 3 years) and a second category in which those ideas and concepts which will find utility in industry beyond a 3 year time frame. Generally, introduction of advanced R&D and sophisticated technology transfer fall into the second. The 3+ years required for the second category are engendered by long lead times in conducting, evaluating and piloting new results as well as designing, purchasing and installing new manufacturing equipment. Since the economic benefits and impacts of the first category of improvements can usually, in concept at least, be evaluated by standard marketing, engineering and cost accounting techniques, this group of advances will not be discussed further (even though final implementation may be hindered by many practical considerations).

Several requirements must be met for successful implementation of sophisticated R&D results of any type in an industrial environment: (1) The uses to which this technology (R&D) is to be put must be very clear to the user. (2) A market must exist for the products that result from the technology and this market must be carefully characterized with regard to costs, competitors, potential profits and constraints such as legal statutes. [MCF-75,1]

Figure E.3.8-1 displays the methodology needed to achieve objectives (1) and (2) above. The first requirement on this figure, to identify high industrial energy users, is well under way as evidenced by this report. An industry data base has been assembled and a methodology for assessing ripple effects (energy conservation in one industry producing energy savings in other areas) developed (input-output analysis). Requirement II is substantially under way; many program speakers have commented on high potential areas of research and technological needs.

Requirement III, assessment of potential energy conservation technology with respect to its suitability for specific applications must be a major focus of successful efforts. Careful delineation of technical requirement is necessary for meaningful conclusions. However, because of the relatively short time available to the Design Group, this requirement was not carried out in the detail necessary for complete analysis. The remainder of the discussion is presented for purposes of illustrating the proposed methodology.

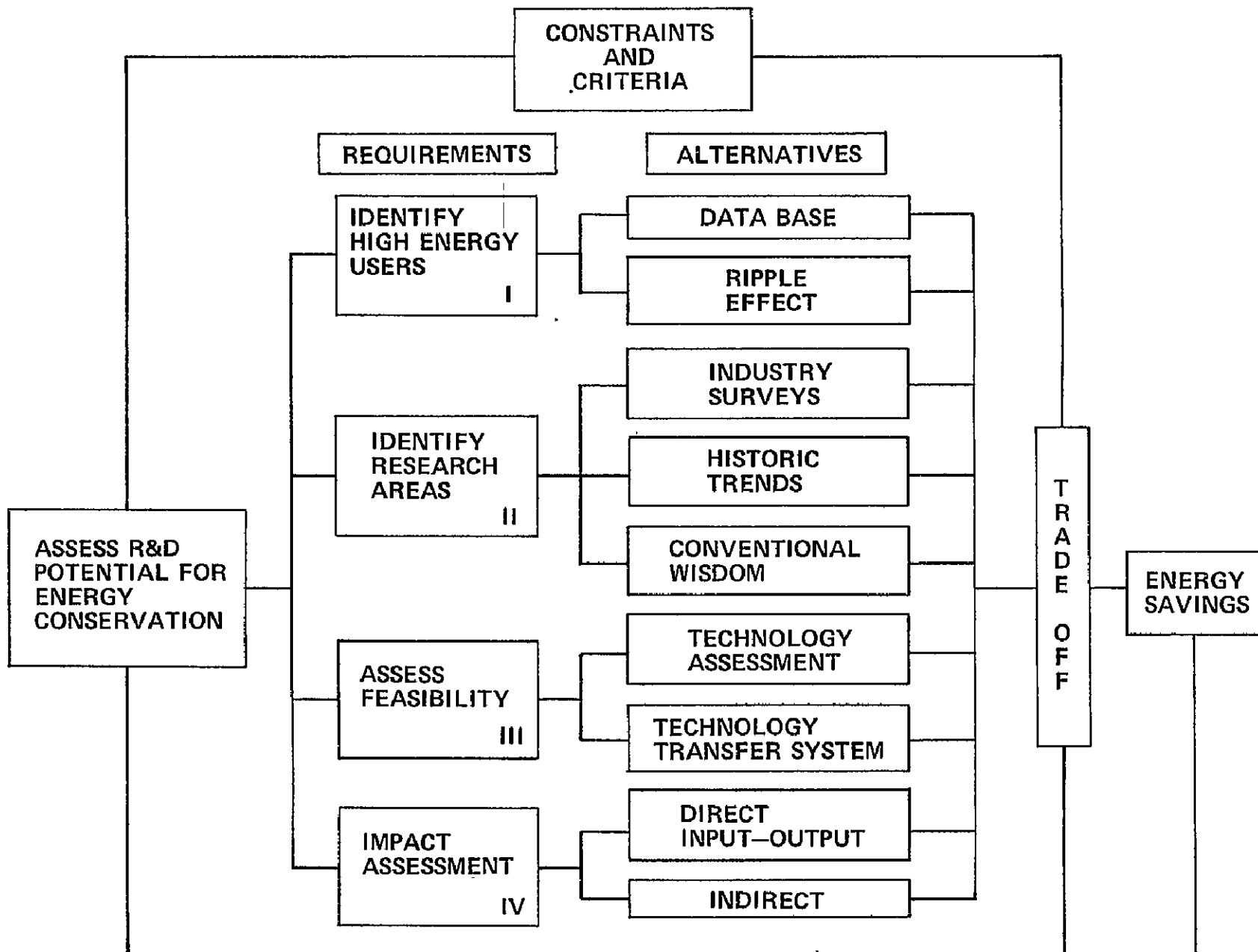


FIGURE E.3.8-1. SUB-SUB-SYSTEM OF REQUIREMENT 3

Research can be divided into three classifications: (1) research done by industry; (2) research done for industry e.g., the ERDA programs [LS-75]; (3) technology transfer to industry. Implementation of results of the first two categories are more straight-forward. Work is conducted by or for an industry with the objective of reducing that industry's energy consumption. Tasks are identified and ranked with respect to well known criteria: priority of potential energy savings, dollar return on investment, etc. Since these activities are generally industry specific; establishment of priorities in any one industry is not excessively difficult. Perhaps the only major uncertainty is determining which industry should receive priority for funds for research done for the industry. Further use of techniques, such as the input-output analysis method this project developed, will aid in assessing where those funds should be best applied.

The third category of research activities, technology transfer, is more difficult to assess. Not only is the question "To which industries should the technology be transferred?" need to be answered, but we must also define which needs in any given industry can be satisfied by the existing technology. Problems in technology transfer are discussed in the literature [KOT-73,24] [CON-73].

Because this category deals with existing technology, it may offer some of the most rapid energy conservation returns. Since it may be the most difficult to implement, examples of preliminary matchings of industrial energy conservation technology needs, and available sophisticated technology (NASA's) are discussed below to illustrate the salient principles. Further efforts are needed to refine matching of existing technologies (assessments).

The major technology need highlighted by Prengle [PRE-75] and others is in improving efficiency of industrial combustion systems. Industry uses 40% of total U. S. energy and about 70% of this is consumed in combustion processes (22 quads). A combustion efficiency improvement of only 5% and introduced in only 25% of U. S. industrial combustion systems would save nearly 0.3 quads. A preliminary discussion with NASA-MSFC combustion experts produced the following suggestions: (1) In liquid rocket fuel systems considerable research and development has been conducted to determine optimum parameters governing mixing of fuel and oxidizer. This is important in rocketry since combustion must occur quickly before the fuel-oxidizer mixture exits the combustion chamber. An analogous situation exists in industrial combustion processes since the better the mixing of fuel and air, the less excess combustion air is needed to completely combust the fuel. (The less excess air used the higher the combustion efficiency.) The suggestion was made that oxidizer (air) in industrial systems could be introduced as a pressurized stream as it is in rocket chambers. Such a design (using NASA design parameters) could decrease the amount of excess air needed for complete combustion. (2) In industrial solid fuel systems (coal) larger amounts of excess air are needed for complete combustion than in liquid fuel systems. Use of NASA solid fuel technology was also proposed as a potential method for alleviating this problem. In solid rocket fuels, solid oxidizer is mixed with the solid fuel to produce burning. Mixing of coal with inexpensive oxidizer (such as ammonium nitrate) prior to burning could generate rapid burning and require less excess air and thereby improve efficiency.



Other ideas developed in conversations with MSFC personnel were applying NASA sensors in excess combustion air monitoring, and use of high temperature metal alloys developed for rockets in industrial turbines, to allow higher operating temperatures (and therefore improved efficiencies).

Additional preliminary matchings are given in Table E.3.8-1 to illustrate the many overlaps between NASA technology and industrial energy conservation needs.

Also needed is a method for moving this technology into the market place. This method, called a technology transfer system, has been discussed [EZR-75,707]. It is shown on the sub-study system's diagram and should be the subject of additional analysis so that it will be suitable for energy conservation technology.

Requirement IV on Figure E.3.8-1, impact assessment method, has been developed by the task group as a whole. Estimates of energy savings in a single industry due to specific technological developments must first be conducted. Then impact assessment, done on U. S. industry as a whole, must be executed through the input-output techniques described in the preceding sections. Energy savings in one industry should be traced through all industry interactions to establish impacts such as total industrial energy savings. Thus complete research and development strategies with well defined benefits (and accordingly high probabilities of success) can be developed.

In conclusion, it seems there are many opportunities for sophisticated technology in general, and for NASA technology in particular to satisfy technical needs which will bring about large scale industrial energy savings. Unfortunately, current NASA plans do not call for aggressively exploiting this area.

#### E.4 GOVERNMENT ACTIONS

As discussed in Chapter 1, legal instruments currently exert major effects on energy usage, pricing and availability in all sectors of the U. S. economy. One program speaker [GT-75,1] commented that all energy prices in the U. S. are in effect set by legal statute rather than the costs of production. Interstate regulation of natural gas prices is one example of this. Clearly, this type of government control impinges on industry in at least two ways; (1) the prices industry must pay for energy are part of the manufacturing cost and consequently influence demand for any industries output and (2) prices consumers pay directly for energy also influences demand (e.g. automobiles, houses, etc.) for industrial commodities.

In this area of energy prices, a major decision is before Congress. The Emergency Petroleum Allocation Act (EPAA) which gives authority to control U. S. crude oil prices is due to expire on August 31, 1975. The president's plan to decontrol oil prices was defeated in the House of Representatives in late July. A bill (S 1849) whose only provision is a six month extension of the EPAA was sent by Congress to the president. Since presidential action was to threaten a veto of this bill, and congressional session adjournment was to precede presidential action, the entire price structure for petroleum

TABLE E.3.8-1. NASA TECHNOLOGY WITH  
POTENTIAL FOR ACHIEVING INDUSTRIAL ENERGY CONSERVATION

<u>Item</u>	<u>Reference</u>	<u>Industrial Application</u>
I. Sensors		
Cryogenic Thermocouples ( $< 50^{\circ}$ K)	[MOE-68,5]	Power Transmission (Cryogenic Super Conductor Monitoring)
High Temperature Thermocouples	[MOE-68,15]	Combustion System Instrumentation
Gas Temperature Measuring Thermocouples	[MOE-68,23]	Glass Manufacture
Energy Transfer Gauges	[MOE-68,55]	Process Heaters
II. Induction Heating	[LEA-69,4]	Rapid Heating Coal Gasification Process
III. Confined Gas Dynamics	[ROB-72,171]	Turbines, expanders

(and consequently other energy sources) is now uncertain. The following Table E.4-1 presents the analysis of the Staff of the House Subcommittee on Energy and Power of the effects of the President's decontrol plan and an alternative to this decontrol, (H.R. 7014). It is apparent that the Staff anticipates major unemployment and reduced GNP if oil price controls are phased out. Mr. F. Zarb, FEA administrator, criticized the Staff analysis on the grounds that they (1) assumed an OPEC initiated oil price increase; (2) did not consider future administration monetary policies that would be changed if large scale undesirable impacts resulted. In any case, the effects of oil price decontrol will be large and far reaching. FEA predicts greatly improved domestic oil supplies, and the Staff warns of large scale unemployment, decrease in GNP, and increasing inflation.

Another area of impact of legislation on industrial energy usage is in efficiency standards. At least three pending federal bills, H.R. 7104, S. 1908, and S. 1149 address this subject. Basically, they call for collecting energy usage data from industry, establishment of efficiency standards, initiation of industrial energy monitoring programs and monitoring of adverse effects due to the initiated legislation. H.R. 7014 specifically calls for the 2000 largest industrial energy consumers to reduce energy/unit output by 20% by 1980 (1972 base). The impacts of such legislation under other than large amounts of direct energy usage will be reduced. Questions such as total capital required, total technical manpower needed (scientists and engineers) have not been well answered. In this respect, it seems apparent that there will be a shortfall of engineers since it is currently predicted [LC-75,1550] that there will not be sufficient engineers for the power industries alone and bills such as H.R. 7014 are also expected to require large numbers of engineers.

To eliminate the need for legislation of the type described above, industry, DOC, and FEA have entered into a joint voluntary program to reduce industrial energy consumption per unit of output. Goals developed in Federal agency meetings with the industries and their trade associations were: [IEC-75-2]

	<u>1980 goal</u>
Aluminum Association (1)	10%
American Iron and Steel Institute	10%
American Paper Institute	10%
American Petroleum Institute	15%
Manufacturing Chemists Institute	15%
Portland Cement Association	10%

(1) 1973 baseline; all others are 1972 baseline

The stringency of these requirements, as they relate to past industry performance is discussed in the sections of industrial energy conservation potential of the major energy users.

TABLE E.4-1. + PROJECTED IMPACTS OF OIL PRICE  
DECONTROL OR IMPLEMENTATION OF HR 7014  
(Projected change in Annual Rates as of: )

ORIGINAL PAGE IS  
OF POOR QUALITY

	'75:4	'76:2	'76:4	'77:2	'77:4
<u>REAL G.N.P. (Billions \$ '58)</u>					
President's Plan - as submitted with FEA analysis	-0.2	-0.5	-2.2	-4.7	not submitted
President's Plan - staff analysis * vs. Current Controls	-0.6	-2.6	-8.3	-17.1	-26.0
H.R. 7014 - staff analysis * vs. Current Controls	+0.6	+2.2	+5.0	+7.9	+8.9
<u>Number of Unemployed (,000's)</u>					
President's Plan - as submitted with FEA analysis	0	0	0	+100	not submitted
President's Plan - staff analysis * vs. Current Controls	0	+100	+200	+500	+800
H.R. 7014 - staff analysis * vs. Current Controls	0	-100	-100	-200	-300
<u>CONSUMER PRICE INDEX %</u>					
President's Plan - as submitted with FEA analysis	+0.08	+0.18	+0.35	+0.57	not submitted
President's Plan - staff analysis * vs. Current Controls	+0.18	+0.46	+0.90	+1.47	+2.06
H.R. 7014 - staff analysis * vs. Current Controls	-0.19	-0.39	-0.54	-0.62	-0.62
<u>WHOLESALE PRICE INDEX %</u>					
President's Plan - as submitted with FEA analysis	+0.03	+0.46	+0.97	+1.53	not submitted
President's Plan - staff analysis * vs. Current Controls	+0.74	+1.73	+3.09	+4.61	+6.13
H.R. 7014 - staff analysis * vs. Current Controls	-0.77	-1.47	-1.65	-1.65	-1.58
<u>HOUSING STARTS (,000's units)</u>					
President's Plan - as submitted with FEA Analysis	-1	-15	-53	-89	not submitted
President's Plan - staff analysis * vs. Current Controls	-4	-51	-177	-273	-268
H.R. 7014 - staff analysis * vs. Current Controls	+8	+41	+78	+83	+28
<u>AUTOMOBILE SALES (,000's units)</u>					
President's Plan - as submitted with FEA analysis	0	0	-100	-200	not submitted
President's Plan - staff analysis * vs. Current Controls	0	-100	-400	-800	-1000
H.R. 7014 - staff analysis * vs. Current Controls	0	+100	+200	+300	+300

+ Based on Data Resources Incorporated Model

\* Prepared by the Staff of the House subcommittee on Energy and Power

Another area of legislative impacts on industrial energy is government funded research and development (R and D). In general R and D is expected to make a large impact on both industrial energy supplies and conservation. Energy supply work is largely to be conducted by ERDA and those preliminary plans are known. Industrial energy R and D (including conservation) will be done in large part by the Inter-Industry Programs Division [LS-75,1] of ERDA. Other Federal Agency energy research work is summarized in a recent publication by Congress. [FEM-71,1] Guides to industrial energy conservation work using currently available technology have been published by the National Bureau of Standards in the EPIC program (Energy Conservation Program in Industry and Commerce) and in a forthcoming publication - The Waste Heat Management Program. The EPIC Program, of which more than 50,000 copies have been purchased by industrial groups, is a general guide to energy conservation practice through such techniques as energy balances, economic analysis, etc. The Waste Heat Management Manual is a more specialized publication dealing with a methodology for maximizing energy savings through waste heat recovery. Both programs will apparently have large influences on industrial practices.

In addition to federal legal action, there are many existing and pending state and local legislative actions. Preliminary evaluations of state laws in some representative states (Florida, Wisconsin, Texas, Oregon, Ohio and Vermont) reveals that very few laws are producing energy conservation and may entail excessive energy usage [GT-75,1]. The total magnitude of such energy usage is unknown.

One characteristic of legislation at this level is that the authority is close to the energy consumer (upon whom the legislation will impact). Possible methods through which the states could implement conservation tactics would be to: (1) direct public utility commissions to set and enforce insulation standards; and (2) to determine power plant sitings to allow industry to utilize waste heat. [GT-75,1] The potential for these actions and the extent to which they will be put into practice is also unknown.

The above discussion leads to the conclusion that government actions influence and control industrial energy usage (and conservation) as much as any other factor.

## E.5 ACTIONS

When the group attacked the problem of conservation in industry, it became evident immediately that finding hard data in any form other than that presented by the National Petroleum Council (Table E.5-1) was going to be a difficult task. Since most reports discuss energy conservation efforts in terms of the overall saving achievable by six of the most energy-intensive industries, determining the energy action is extremely difficult. The diversity within a particular industry, in addition to the diversity within the industrial sector itself, complicates the problem. One of the obstacles that has been encountered by investigators trying to estimate the potential for energy savings is the fact that until the embargo most industrial records of energy use were limited to the quantity and cost of

TABLE E.5-1. ESTIMATED CONSERVATION POTENTIAL  
INDUSTRIAL SECTOR -- 1974-1978  
(Based on 1972 Energy Consumption) [NPC-74,28]

<u>Industry</u>	<u>Potential Savings Per Unit Of Output (Percent)</u>
Primary Metals (Steel, aluminum, etc.)	5*
Chemicals	20
Petroleum Refining	15
Agriculture	
Farming	2
Food Processing	10
Automobile Manufacturing	10
Paper	15
Remaining Industries	<u>10</u>
Weighted Average	10

\* The 5 percent savings for primary metals is extrapolated from the steel and aluminum projections as these metals make up the primary portion of the primary metals group.

This Table summarizes the estimated potential savings of energy through conservation efforts for the individual industries through the 1974-1978 period. These figures represent potentials for the industries on the average and should not be viewed as necessarily applicable to individual companies where past conservation measures may have already effected a significant savings.

the various fuels, seldom having an accurate indication of time of consumption or flow within the plant. Since such records were inadequate for a detailed analysis, industries (who are generally interested in conserving energy only in cases where the economics favor conservation) first had to spend time mapping the energy flow and use within their plants.

When the task group first began trying to identify conservation actions in the industrial sector, an attempt was made to categorize the actions under the broad topics -- increased efficiency, reduced demand, and substitution. It became evident very quickly that time would not allow each member of the task group to familiarize himself with each of the six industries chosen for study. Therefore, it was decided that each member would try to familiarize himself with conservation actions within an industry. After collecting data on various conservation actions, it was decided that such actions could generally be grouped into three categories: (1) improved combustion efficiency, (2) process improvements, and (3) good housekeeping measures. A non-inclusive list of conservation actions is included in Section E.5.5.

#### E.5.1 CONSTRAINTS -- AN OVERVIEW

In general it has been found that since the Arab embargo, industry has been taking advantage of the energy savings inherent in performing many of these good housekeeping measures. For example, the refining and chemical industries have already achieved a 7.5% reduction in energy consumption [Wells - 75]. Since most conservation actions included in the good housekeeping category are actions requiring little or no capital investment, these actions were most attractive in terms of energy savings as well as from an economic point of view.

With regard to conservation actions in the other categories, industry, in general, treats those measures involving capital improvements the same as any other capital outlay. That is, investment should take place up to the point where the rate of return is equal to the opportunity cost of alternative investment projects. The measures considered must not only meet this criteria, but generally must have a payback period of less than two years [EEA-74,4-24].

According to one study [PRE-75], the economics of rising fuel costs will probably be sufficient incentive for industry to conserve fuel even though capital investment will be required. Since capital dollars used to improve energy efficiency will not be available for other improvements, there may be a conflict of interest in certain areas, for example, environmental regulations requiring large capital investment. The government should be aware of this requirement for capital investment and the possible conflict of interest.

Another extremely important constraint on industry that has a decided effect on energy consumption and capital requirements is curtailment of natural gas. Since conversion away from natural gas toward other fuels

has been taking place at a rapid rate, some capital investment has already been committed and additional capital will be required for these conversions. Consequently, even though this conversion may be sensible from a national policy perspective, in the short run it is a drain on financial resources. Also, fuel conversion typically involves an energy penalty. It is obvious from the outspoken position of many companies in favor of deregulation of natural gas prices that availability is more important than price. In fact, insuring the availability of fuel supply is such a significant consideration in some industries that they have expanded their investments in coal mines and are considering investments in low BTU coal gasification. Even though such investments are understandable from an industrial perspective, this commitment of capital will reduce the capital available for energy conservation action, which, in turn, will result in an overall energy penalty.

In some instances the possibility of conserving fuel will be limited by facts outside the control of the industry -- for example, glass container production is expected to decrease by 20% by 2000 due to the conversion from nonreturnable bottles and to reduced glass container volume. The substitutes intended to replace glass containers should be analyzed carefully in terms of whether or not this action will be less energy intensive before the switch is made. Much controversy has already arisen concerning the net energetics of returnable vs. nonreturnable glass containers.

Another example of a constraint imposed on an industry from outside is the specification of octane quality for gasoline. There is a direct relationship between product quality and energy consumption within the refining industry. During the 1950's, automobile manufacturers increased compression ratios to achieve better automotive performance. This trend continued through the sixties forcing the petroleum industry to improve the octane quality of gasoline. One method used by the industry was to add tetraethyl lead to the gasoline pool. This trend was reversed in the early 1970's with the advent of emission control systems, and in 1973 the U. S. Environmental Protection Agency promulgated regulations restricting the use of lead in gasoline. Unless the octane quality of the entire gasoline pool is significantly reduced, the production of gasoline with reduced lead content levels could result in a significant increase in energy consumption per barrel of refined product [EEA-74].

Additional constraints which apply to the industrial sector in general include:

- in the face of rising coal demands, a continued decline in coal quality will lead to energy penalties;

- deteriorating fuel quality and the desire to reduce dependence on foreign supplies may boost energy usage;

- lower output growth will tend to perpetuate use of less efficient installations.

Additional possible constraints identified by the National Petroleum Council's study [NPC-74, 28] are the availability of technical manpower and environmental concerns.



There is strong industry concern over the availability of technical manpower to identify, evaluate and implement energy conservation projects. There is a general engineering manpower shortage, and demand for operation, modernization and expansion will compete with energy conservation needs. Small companies with limited technical staffs will find it difficult to assign the necessary technical effort to energy conservation [NPC-74, 29].

Energy conservation programs are sometimes in conflict with environmental standards. These standards may necessitate process changes that result in increased use of energy. An example is the reduction in coke production in the steel industry due to problems in meeting air and water quality standards, which, in turn, has increased the use of direct oil injection in blast furnaces. Another example is in petroleum refining where desulfurization of residual fuel oil to comply with environmental regulations applicable in many areas requires an equivalent of 3 to 4 percent of the quantity of oil desulfurized as energy for the desulfurization process [NPC-74, 29]. Increased emphasis on pollutant removal from water and air released from pulp and paper mills tends to increase energy consumption.

These and other constraints will be extremely important in determining energy consumption and savings in the industrial sector. Sections E.5.2 and E.5.3 will be devoted to a discussion of some general actions under the categories increased combustion efficiency and process improvement.

#### E.5.2 INCREASED COMBUSTION EFFICIENCY

As can be seen from the non-inclusive list of conservation actions presented in Section E.5.5, there is a host of conservation actions which can be grouped under the increased combustion efficiency category, which has been identified as one of the areas of greatest potential savings [PRE-74, 3-4].—Much of the energy lost in the industrial sector could be avoided through better equipment maintenance and improved systems control. By far the most important item in this group is fire heater combustion control.

Efficient firing of fuel is extremely important. For example, according to one study [EEA-74, 4-13] direct process heating fuel requirements accounts for 78% of total refinery energy consumption. Insufficient fuel combustion generally results from two factors: (1) excess air in the combustion chamber and (2) operating heaters in excess of designed heat duties. Excess air leads to inefficiencies as the heat liberated in fuel combustion is wasted in warming up the excess air. Careful control through the use of louvers or dampers can increase heater efficiencies in many cases by as much as 10 to 15%. Caution must be exercised, however, because insufficient air intake can lead to incomplete combustion. The operation of heaters in excess of designed heat duties leads to heat losses primarily in the form of stack gas energy losses. Monitoring stack gas temperatures can provide an efficient technique for determining if heat duties are in excess of requirements. As a rule of thumb an adjustment which reduces the amount of excess air from 20% to 10% will lead to a fuel savings of 1% [EEA-74, 4-18].

Assuming that 70% of the energy consumption is involved in combustion, approximately 0.15 quads could be saved in 1980 and .18 quads in 1985 using EEA's projected energy consumption by all manufacturing [EEA-74, 1-32].

$$22.2 \text{ quad} \times .70 \times .01 = 0.15 \text{ quads in 1980}$$

$$25.9 \text{ quads} \times .70 \times .01 = 0.18 \text{ quads in 1985}$$

### Power Generation Vs. Purchased Power

Energy savings can be achieved by combining power generation with process heating, as shown in Figure E.5.2-1. In this case the turbine operating conditions will be determined by the process in order to fully utilize the exhaust steam. In processes when low pressure steam is utilized, this scheme is most attractive. If more electricity is generated than can be used internally, it may be sold to the utility. Obviously there are substantial obstacles to implementing this action -- some of which will be addressed in Section E.6.

According to the Center for Advanced Computation's numbers, approximately 9.6 quads were used for process steam in 1967 [CAC-75, 133-40]. This represents about 65% of the total energy used by the manufacturing sector (14.765 quads in 1967 according to the data in the EEA study) [EEA-74, 1-32]. Using the EEA study projections and this 65%, 14.43 quads will be used for process steam in 1980 and 17.0 quads in 1985.

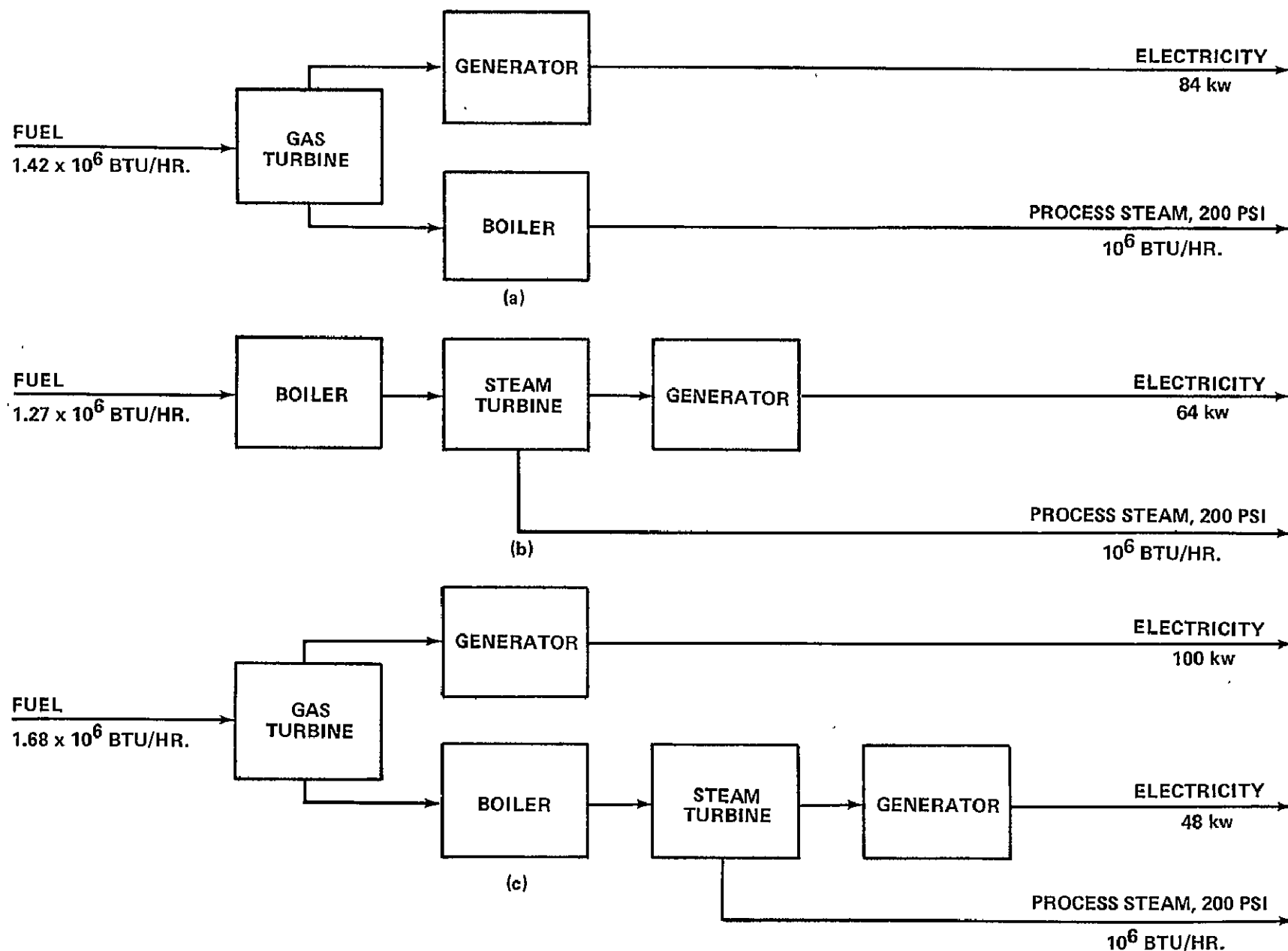
According to the analysis presented in Potential Fuel Effectiveness in Industry [PFE-74, 74], about 70 KW of electric power can be obtained for every million BTU per hour of steam required by industrial processes. Accepting this value for available electricity / $10^6$  BTU/hr, and accepting the EEA study's estimates of future consumption, and then correcting for the incremental fuel consumption (43%) used for electrical generation results in the following approximate savings (assuming that this conservation action were implemented by the entire manufacturing sector):

$$14.4 \times 10^{15} \frac{\text{BTU}}{\text{yr}} \times \frac{70 \text{ KW}}{10^6 \text{ BTU/hr}} \times \frac{3.412 \times 10^3 \text{ BTU}}{\text{kWh}} \times \frac{1}{.34} \times .43$$

$$= 4.36 \text{ quads in 1980}$$

$$5.14 \text{ quads in 1985}$$

Gyftopoulos calculates that the steam flow in U. S. industry in 1968 ( $10.2 \times 10^{15}$  BTU for process steam) could have generated  $7 \times 10^{11}$  kWh or 53% of the total U. S. electrical production in that year. The net fuel savings would have been 4.0 quads or 30% of all fuel used by the electric utilities [PFE-74, 27].



COMBINED PROCESS STEAM RAISING AND ELECTRICITY GENERATION SCHEMES FOR PROCESS STEAM AT 200 PSI AND  $10^6$  BTU/HR.

FIGURE E.5.2-1.

Obviously, many industrial operations requiring process steam are too small in scale to permit economical generation of by-product electricity. However, an opportunity does exist for an enormous fuel savings if such practices are implemented on a broad scale. For example, if one assumes that only fifty percent of this savings can be achieved, the savings is still significant -- 2.18 quads in 1980 and 2.57 quads in 1985. The saving per major industrial sector based on its percentage of process steam according to CAC data is presented in Table E.5.2-1.

Implementation of this type of conservation action will require the development of markets for by-product power through utility networks since many industries will become net producers of electricity. In other words, the expanded production of by-product power will not be aimed at the electrical needs of industry but at the national problem of fuel conservation. Obviously cooperation between industry and the utilities will be required. The effect of this type of action on the peaking problem and the need for utility expansion should be evaluated. Industry may be reluctant to implement this type of action unless they feel more secure about their fuel source. Perhaps the assurance of fuel supply would be a strong incentive for implementation. In addition, there is an economic incentive for implementation as shown by the following calculation based on Table E.5.2-2. The incremental capital cost in ¢/kWh can be found for various process pressures in Table E.5.2-2. Averaging these capital charges and assuming that only 50% of the industries implement cogeneration results in a capital cost of  $\$2.42 \times 10^9$  by 1980:

$$14.43 \times 10^{15} \text{ BTU} \times \frac{70 \text{ KW}}{10^6 \text{ BTU/hr}} \times .48¢/\text{kWh} \times .50 =$$

$$\underline{\$2.42 \times 10^9 \text{ capital cost}}$$

In Table E.5.2-2, the capital charges range from 0.33 to 0.60¢/kWh and are much the same for steam turbines and gas turbines. The total of fuel and capital charges ranges from 0.74 to 1.10¢/kWh. It would seem reasonable to put the cost in practice at approximately 1¢/kWh, which may well be a profitable figure at pre-Arab embargo fuel costs. If fuel costs were to double, this figure would increase by less than 50%, whereas costs in a central-station plant would doubtless increase by a larger percentage since 1 kWh generated by the combined plant requires about 4300 BTU while that generated by a central-station plant requires 10,000 BTU. [PFE-74,26]

The cost figures include no incremental labor charge. If any, it should probably be added as a charge per hour of power generation. Thus, for an incremental charge of \$1.00 per hour applied to operating hours, the labor cost would be 100/P cents per kilowatt hour when P kilowatts are generated. For values of P in excess of 1000 KW, the labor cost need not be prohibitive. [PFE-74, 27].

TABLE E.5.2-1. POTENTIAL SAVINGS USING 50% CO-GENERATION<sup>a</sup>

	1980 Quads	1985 Quads
Food and Kindred Products	.17	.20
Paper	.24	.28
Chemicals	.47	.56
Refining	.41	.48
Stone, Clay, Glass	.25	.30
Primary Metals	.38	.45
Other	.25	.30

These savings would be obtainable only if 50% of the manufacturing sector had implemented this conservation action by 1980 and 1985. Obviously, this is an extremely important assumption and it needs to be evaluated in terms of its potential and percent achievability.

<sup>a</sup> Calculated from data from [CAC-75,133-140]

ORIGINAL PAGE IS  
OF POOR QUALITY

TABLE E.5.2-2. CAPITAL AND FUEL CHARGES AGAINST ELECTRICAL POWER AS A BY-PRODUCT OF PROCESS HEAT\* [PFE-74, 26].

Process Pressure, psi	200	200	400	200	50
Power-Unit	Steam & Gas Turb.	Gas Turb.	Steam Turb.	Steam Turb.	Steam Turb.
Gas-Turbine cost	10,000	8400	-	-	-
Steam-Turbine cost	2400	-	1700	2450	3850
Boiler Increm. cost, \$	4250	0	740	4030	4630
Boiler Cost without power	2930	2930	5860	2930	2930
Boiler cost with power	7180	2930	6600	6960	7560
By-product power, KW	148	84	34	49	77
Heating value to boiler x 10 <sup>-6</sup> , BTU/hr	1.23***	1.0**	1.20	1.27	1.37
Total increm. capital	16.650	8400	2440	6480	8480
Capital charge, ¢/kWh	0.51	0.46	0.33	0.60	0.50
Fuel Charge/ ¢/kWh	0.41	0.41	0.41	0.41	0.41
Capital and fuel charge/ ¢/kWh	0.92	0.87	0.74	1.01	0.91

\* Units are 10<sup>6</sup> BTU/hr delivered to process steam, fuel input rates are based upon higher heating values.

\*\* Heating value to gas turbine 1.42 x 10<sup>6</sup> BTU/hr.

\*\*\* Heating value to gas turbine 1.68 x 10<sup>6</sup> BTU/hr.

As can be seen from Table E.5.2-2, Gyftopoulos assumes a 0.41 fuel charge, which would result in a  $\$2.07 \times 10^9$  fuel cost for 1980:

$$14.43 \times 10^{15} \text{ BTU} \times \frac{70 \text{ kW}}{10^6 \text{ BTU/hr}} \times .41¢/\text{kWh} \times .50 =$$

$$\$2.07 \times 10^9$$

Thus, a total cost of about  $\$4.5 \times 10^9$  would be incurred by industry. However, if the generated electricity could be sold at about 1.60¢/kWh [average value extracted from FOSTER-74, 8], resulting in a  $\$8.1 \times 10^9$  return, the payback period would be less than a year. Obviously the salaries of the additional skilled employees required has not been considered.

The capital and fuel cost per industry assuming 50% implementation by 1980 is shown in Table E.5.2-3, assuming the same percentage of process steam as in Table E.5.2-1.

Obviously, this kind of a breakdown for capital cost and return by industry is not very meaningful until someone looks into exactly how much electricity each industry really could supply. However, it is interesting that 0.3 quads savings compared to 0.41 can be predicted for the refining industry by another indirect calculation (but based on Gyftopoulos's numbers). Using the  $590 \times 10^6$  tons output in 1968 and Business's Outlook's capital output figures for that year one can obtain the dollars/ton ratio which can then be used with the capital output projection to estimate total output in tons for 1980 and 1985. Then using Gyftopoulos's estimates of  $0.43 \times 10^6$  BTU/ton savings [PFE-74, 57] in the refining industry yields 0.3 quads: \_\_\_\_\_

$$\frac{5.90 \times 10^8 \text{ ton}}{\$2.67 \times 10^{10}} \times \$3.18 \times 10^{10} \times \frac{0.43 \times 10^6 \text{ BTU}}{\text{ton}}$$

$$= 0.30 \times 10^{15} \text{ BTU} = 0.30 \text{ quads in 1980}$$

$$\frac{5.90 \times 10^8 \text{ tons}}{\$2.67 \times 10^{10}} \times \$3.43 \times 10^{10} \times 0.43 \times 10^6 \text{ BTU} = 0.33 \text{ quads in 1985}$$

Additional problems related to industry's increasing its internal power generation include erratic steam demands, smaller scale compared to utilities and anti-trust issues. All of these issues must be considered before the type of action is implemented. One example of this action and the resulting legislative action is discussed in Section I.4.

On the other side of the picture, the utilities will probably not be very optimistic about this type action since they would no longer be the producer and may be the intermediary in electrical production in this case. Obviously, the phase-in would have to be scheduled in cooperation with utilities in order to insure sufficient electricity but not an over supply.

TABLE E.5.2-3. CAPITAL AND FUEL CHARGE

(BILLIONS \$)

	<u>1980 Cost</u>	<u>1980 Return</u>	<u>1985 Cost</u>	<u>1985 Return</u>
Food and Kindred Products	.35	0.63	.41	.69
Paper	.49	0.88	.58	1.00
Chemicals	.98	1.76	1.15	1.99
Refining	.85	1.51	.99	1.71
Stone, clay, glass	.52	0.94	.62	1.06
Primary metals	.78	1.30	.94	1.69

Along with the type of power recovery scheme discussed above is the possibility of recovering useful work from steam, waste flue gases and process steam.

Typical examples would include:

Steam pressure reduction by let-down through a turbine to drive a process pump. The exhaust steam in turn being used for process heat;

Steam let-down through a turbine to drive an electric generator;

Steam let-down through a thermocompressor to recompress low pressure waste steam to some intermediate level;

Use of catalytic cracking regenerator gas (in a refinery) to drive turbines and generate power, and

Use of hydraulic turbine to recover energy from high pressure liquid streams.

### Hydraulic Turbines

Hydraulic turbines are used to recover power from high pressure process streams. Shell Oil has 18 hydraulic turbine installations ranging from 230 to 1,800 horsepower and, according to Shell, units below the 230 HP range will not become more attractive as energy prices increase.

### Energy Savings

The energy savings will vary depending on the size of the unit. One example provided by Shell for a 500 HP hydraulic turbine demonstrated that the yearly power savings from a unit of this size would be roughly 3.2 million kWh.

The incremental cost of the unit was approximately \$50,000. At 9 mills per kilowatt hour this unit would have resulted in a payback of 1.73 years, i.e. (yearly savings):

$$(3.2 \times 10^6 \text{ kWh}) \times \$0.009 = \$28,800$$

Thus, the payback on recovery is

$$\frac{\$50,000}{\$28,800} = 1.73 \text{ years [EEA-74, 4-28]}$$

At the higher energy prices presented below the payback is much more attractive as shown in Table E.5.2-4. Undoubtedly, at these energy prices which range between \$.0303 and \$.041 per kilowatt hour, investments such as these should be exploited. Shell's 18 hydraulic turbines have resulted in a new savings of 65.6 million kwhr ( $6.54 \times 10^{11}$  BTU) per year which is about 3.5% of their yearly electrical bill. [EEA-74, 4-28].



TABLE E.5.2-4. PAYBACK

Case	Reference (\$/bbl crude)	Savings (\$)	Payback (years)
I	\$4.00	\$96,960	.52
II	7.00	111,680	.45
III	11.00	131,200	.38

### E.5.3 PROCESS IMPROVEMENT

As can be seen from the non-inclusive list of conservation actions in Section E.5.5, there are a number of actions that can be grouped under the process improvement category. Two of these actions -- air preheating and recycling -- are discussed in this section.

#### E.5.3.1 REGENERATIVE AIR PREHEATING

Heat recovery from stack gases which contain 12-25% of heat liberated by the fuel combustion can be accomplished in two ways:

install tubes in the stack and pass process liquid through the tubes to absorb heat; and

use exhaust gases to preheat combustion air.

The use of stack gases to heat process liquid is widely practiced. However, there still exist many opportunities to improve the degree of heat recovery by this method. The use of combustion air preheaters, a more recent development, is one of the most promising conservation actions in energy conservation.

Air preheaters are used to heat cold combustion air by transferring heat from escaping flue gases. One air-preheat system is shown in Figure E.5.3.1-1.

#### Energy Savings

Studies have shown that inclusion of a regenerative air-preheater system can result in a 10-15% increase in furnace efficiency which represents a 15-25% fuel savings (2.3 to 3.9 quads in 1980 and 2.7 to 4.5 quads in 1985). Table E.5.3.1-1 shows a comparison of boiler efficiency with and without air preheaters. The net energy savings is roughly 17.4 MMBTU per hour which would reduce energy consumption by roughly 16% [EEA-74, 4-26].

Air preheaters may generally be added to existing furnaces without difficulty and are being incorporated increasingly in new plants. As with convection sections, the use of a preheater is governed by economic considerations. Estimates of the energy savings, operating costs, capital cost of the unit and estimated payback period at various energy prices as presented by the EEA study are shown below [EEA-74,4-26].

#### Energy Savings

$$17.6 \text{ MMBTU per hour} \times 9000 \text{ hrs per year} = 140.8 \times 10^9 \text{ BTU}$$

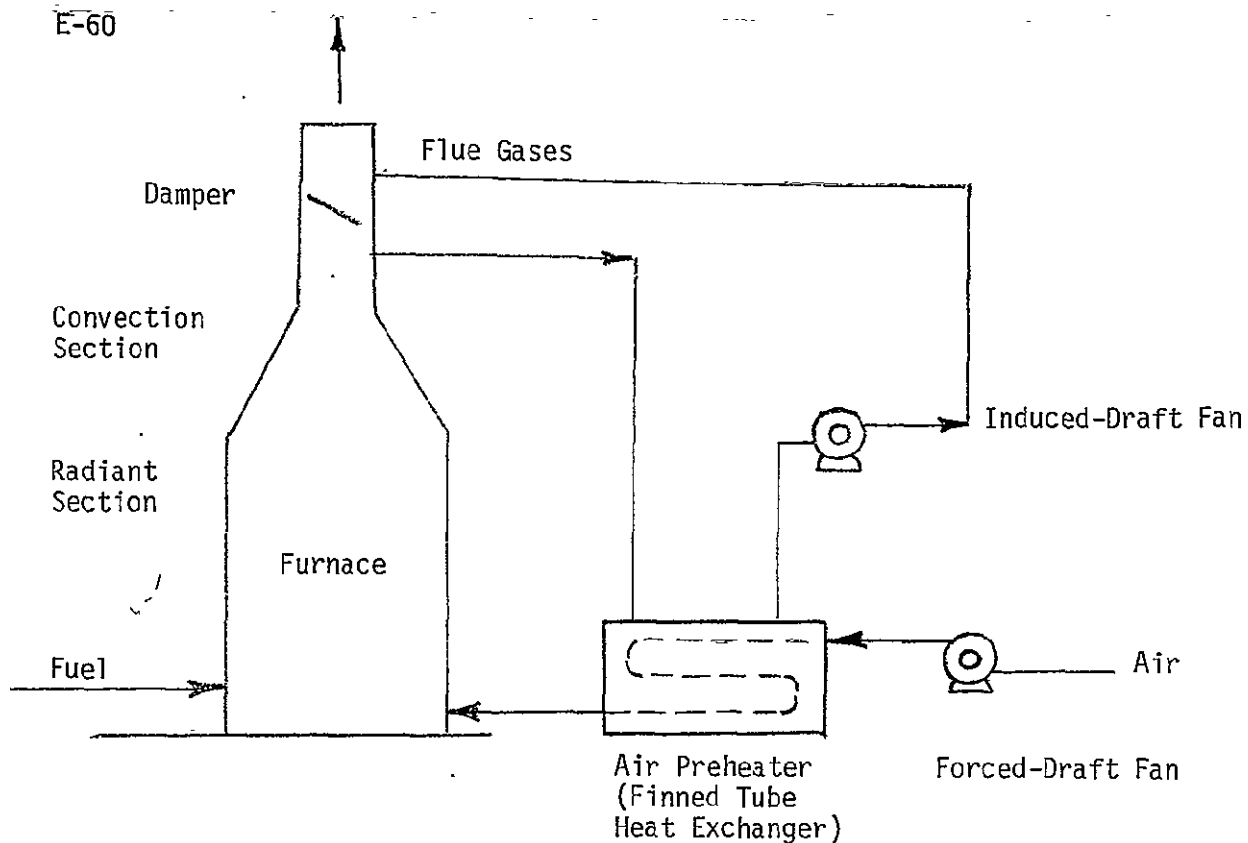


FIGURE E.5.3.1-1. AIR-PREHEAT SYSTEM [PRE-74, 8-20]

TABLE E.5.3.1-1.  
COMPARISON WITH AND WITHOUT AIR PREHEATERS [EEA-74,4-26]

		Without Air Preheater	With Air Preheater
Absorbed Duty	MMBTU/hr	83	83
Ambient Air	°F	80	80
Gas Temp to Air Heater	°F	--	660
Gas Temp leaving Air Heater	°F	--	319
Gas Temp to Stack	°F	815	291
Excess Air	%	30	15
Furnace Efficiency	%	75.7 LHV	90.2 LHV
BTU's Fired	MMBTU	109.6	92.0

Energy Savings = 17.5 MMBTU/hr

### Energy Cost

Operation of the induced draft fan (70.8 hp), the forced draft fan (36.8 hp) and the air preheater motor (1.5 hp) would require  $6.51 \times 10^5$  kWh:

$$109.1 \text{ HP} \times 0.746 \text{ KW/HP} \times 8000 \text{ hr} = 6.51 \times 10^5 \text{ kWh}$$

At 0.015¢/kWh the operating cost would be \$9,770 compared to the operating cost without the preheater system -- \$140,800 at \$1.00/MM BTU -- resulting in a net savings in operating cost of \$131,030 per year [PI-74-7, 149].

### Capital Cost \$125,000 [EEA-74, 4-26]

This cost includes the total cost of the system including installation. Another estimate of the increased cost for the preheater system, as built on a new heater, is of the order of \$250,000 [PI-74, 7 - 149].

### Payback

The calculations in Table E.5.3.1-2 show that under any of the fuel price scenarios this particular investment provides for less than a two-year payback period. The impact of the higher fuel price is to reduce the payback period from 1.5 years to .5 years. An economic analysis of air preheater systems can also be found in Prengle's work [PRE-74, 8-32].

Using Prengle's total capital investment versus heat recovered plot (Figure E.5.3.1-2) resulted in the following capital investment for the quad savings estimated for industry as a whole if air preheaters were installed:

	1980	1985
Quads	2.3 - 3.9	2.7 - 4.5
Investment ( $10^9$ )	\$.20 - \$.30	\$.22 - \$.34

### E.5.3.2 ACTION -- INTRODUCTION OF PREVIOUSLY PROCESSED MATERIALS INTO THE PRODUCTION STREAM

The total output of a manufactured product is the sum of primary and secondary production. Most frequently, the secondary production includes recycled materials as outputs from processing products (old scrap). Less frequent, but just as important, are the introduction of filler materials which are less energy intensive but which provide an end product with the desired properties. The secondary production takes advantage of the previous energy history of the material with the tendency to reduce the energy per unit total output.

TABLE E.5.3.1-2.

EFFECT OF OIL PRICE ON PREHEATER PAYBACK PERIOD [EEA-74, 4-27].

	Payback Period (Years)	Energy Savings/Year (\$1000)	Operating Cost/Year (\$1000)	Net Savings/Year
Case I (\$4/bbl)	1.5	\$102.8	\$19.7	\$83.1
Case II (\$7/bbl)	.85	169.0	22.7	146.3
Case III (\$11/bbl)	.54	259.1	26.7	232.4

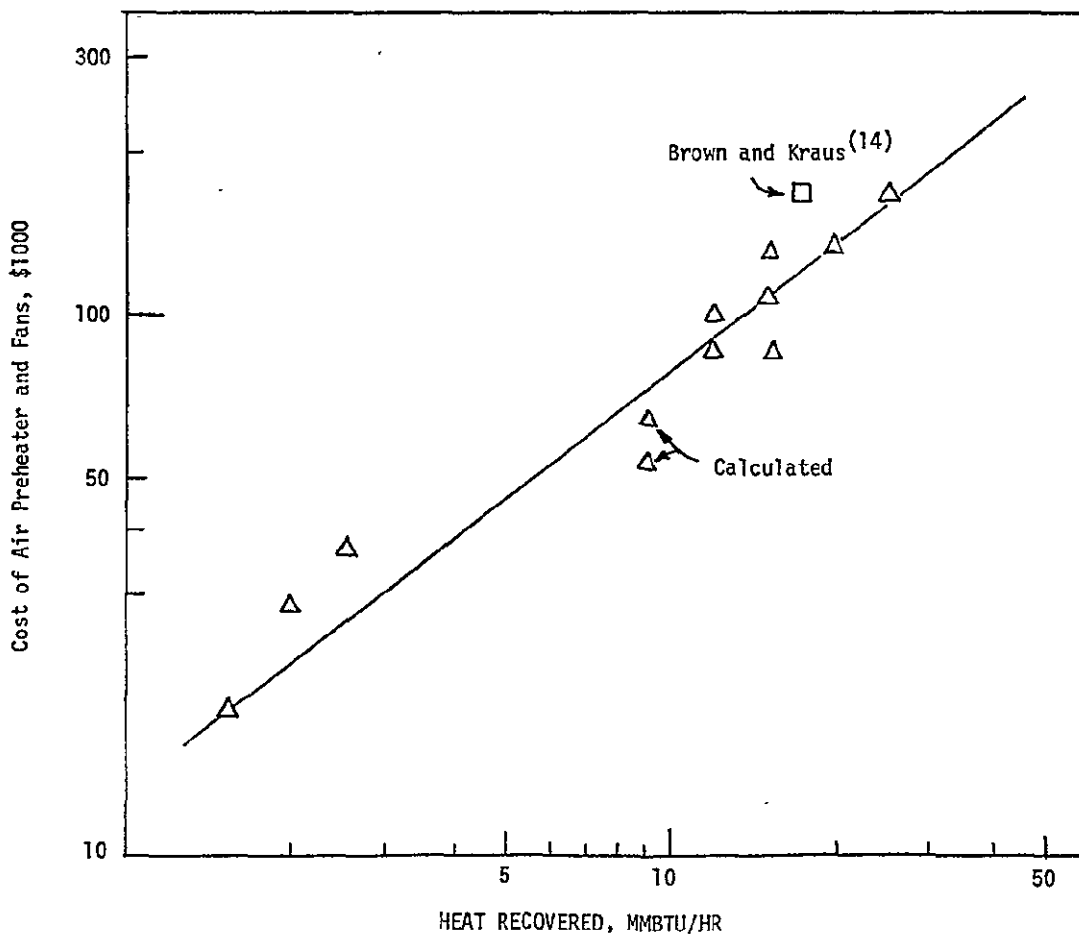


FIGURE E.5.3.1-2. CAPITAL INVESTMENT VS. HEAT RECOVERED [PRE-74, 8-38]

The use of pre-processed materials in production is governed by some general requirements: the scrap must be collected, transported, separated, and prepared. Each of these requirements poses a special set of conditions for each different manufacturing process.

The matter of time frame is generally handled in the near term (1985). The feasibility depends heavily on capital requirements and growth of demand for the product.

The obstacles of secondary production are the reliability of supply and the useful lifetime of products. Inherent in both are the attitudes and willingness of the demand sector to participate in the production process. Frequently, difficult preparation steps are required prior to the introduction of materials into production.

Since the waste stream is a vital source of the materials of secondary production and the waste stream is primarily in the social and political domain, it is necessary to make some political and social impact to accomplish the collection of old scrap. In the short term economics will play a vital role in determining the supply of scrap. In the long run, the design of the channel for the waste stream will be a vital concern. Ultimately, the system must be economically attractive, capable of reliable recovery, environmentally sound, and suitable for the long term.

There are several major industries where scrap can and will play a vital role as the raw material for secondary production -- aluminum, steel, glass, paper, and cement.

Figure E.5.3.2-1 shows a simplified aluminum flow diagram. It illustrates the difference in fuel input between primary and secondary production. The secondary production requires only 5% of the fuel needed which demonstrates a highly effective way of reducing fuel requirements (0.2 quad savings). Assuming that all discarded products (consider lifetimes in Table E.5.3.2-1) and 14% of total production of new scrap, the recycling rate is 33%. The technical feasibility is good. The obstacle is the reliability of supply. The impact of major production would be to reduce the import of ore (bauxite). As the imported ore is not a direct energy cost there may appear to be some loss in the energy accounting.

Recycling scrap steel with pig iron in the refining process is a secondary production process. Assuming a large cold metal charge (98%) the savings are large  $\approx 1$  quad. [EEA-74] However, in this instance there is a large capital expenditure as there must be a shift from the open hearth furnace to the basic oxygen furnace and the electric furnace. There is good technical feasibility but the economics are unfavorable unless there is growth in the industry. A shift in the technology would make impact in the energy supply industry by causing a major shift in fuels.

The glass industry is using new scrap to a small extent with a potential savings of 0.006 quads. There is a reluctance to use old scrap because of the excessive problems in preparation. It may be possible to

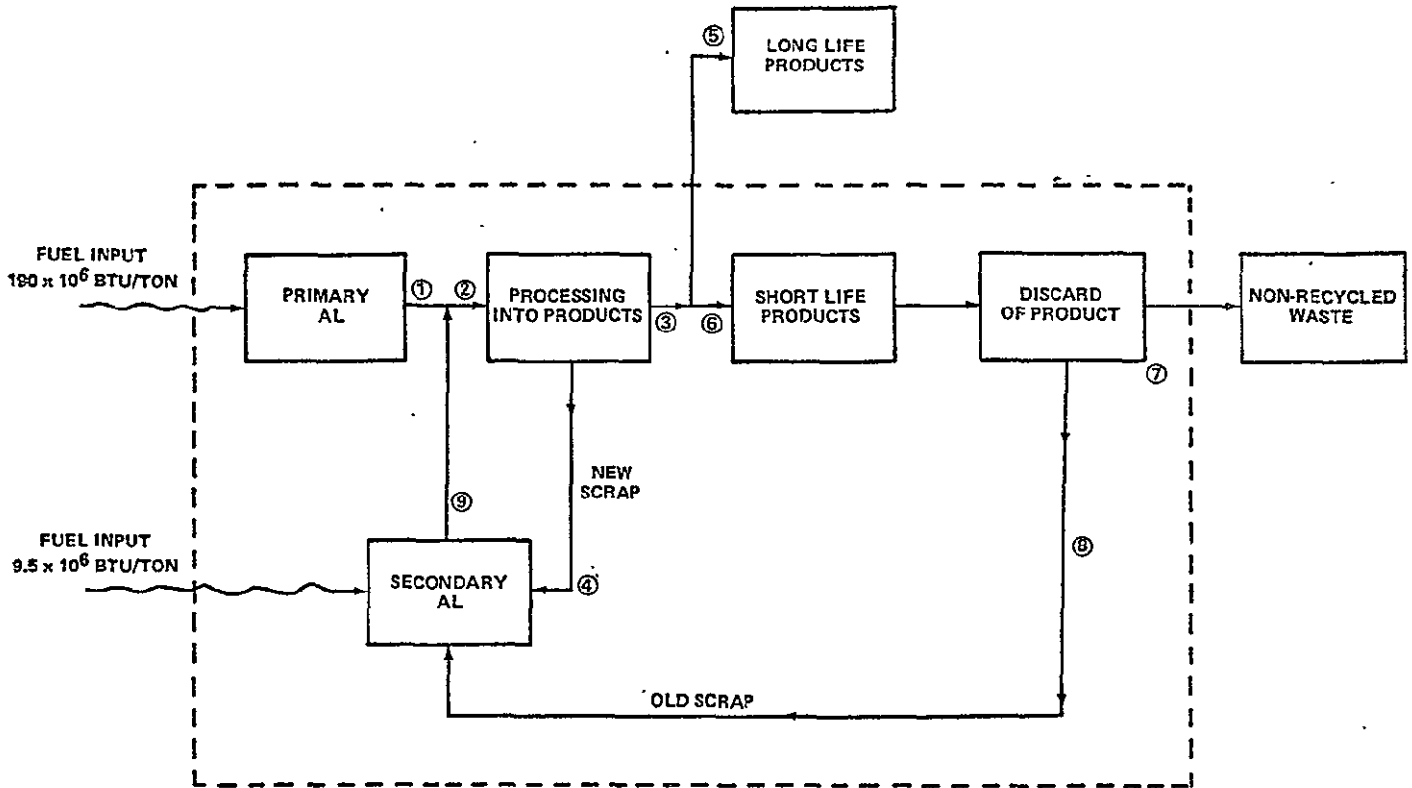


FIGURE E.5.3.2-1. SIMPLIFIED ALUMINUM FLOW DIAGRAM

TABLE E.5.3.2-1. AVERAGE USEFUL LIFETIMES FOR ALUMINUM PRODUCTS [PFE-74,74].

END-PRODUCT USE	% OF TOTAL CONSUMPTION	AVERAGE PRODUCT LIFETIME
Building and Construction	28.1%	Infinite
Other	7.4%	Infinite
Transportation	18.2%	5 years
Containers and Packaging	15.4%	2 years
Electrical	14.5%	25 years
Consumer Durables	9.8%	5 years
Machinery and Equipment	6.6%	10 years

utilize scrap in other products such as insulation materials where preparation of the scrap would be less of a problem. Glass recycling is, however, dependent on the use of glass containers and there are indications that there will be a reduction in the use of glass containers; a short term recycling solution may be attractive.

Recycled paper requires less than 1/4 as much fuel as paper made from the raw wood product. One obstacle would be a parallel development to use paper as a fuel. This would eliminate any energy savings in using recycled paper in secondary production.

Cement poses a unique opportunity to use a material by-product from combustion (fly ash) as a substitute material in cement production. It is estimated that as much as 20% may be substituted with nearly a direct energy savings (0.08 quads) [Faber-75].

#### E.5.4 SPECIFIC ACTIONS BY INDUSTRY

In this section, the conservation actions in both the general and specific categories are identified by industry. This section simply shows how certain actions were first identified by industry and then expanded to the industry sector as a whole.

##### E.5.4.1 REFINING

###### Refining

The major energy consumers in the refining process are the direct-fired heaters. Though the process heaters—crude heaters and vacuum heaters have efficiencies of 75 and 80% respectively, there is still room for improvement.\* Reducing the stack temperature to 350°F will result in a savings of 7.5 M BTU/hr. This would yield a savings of 9.2 M BTU/hr or  $7.4 \times 10^{10}$  BTU/hr. Air preheating, better insulation, reduction in stack gas temperatures and decreasing the excess air can improve efficiencies to 90%. This would yield a savings of 31.3 M BTU/hr or  $2.5 \times 10^{11}$  BTU/hr, or a 17.5% reduction in fuel usage [PRE-74, 4-19].

Another important area of energy consumption is the distillation columns. The use of steam in the columns should be investigated to see if there is an over use of steam. A 2% savings in steam usage will result in a savings of  $1.85 \times 10^{10}$  BTU/hr. Added savings can result from optimizing the side refluxes on each column as feed composition changes. This can be achieved by computer control. Also regulating the vacuum pressure with changes in feed composition will also conserve energy [PRE-74, 4-20].

---

\*The crude heater has a damper control to regulate excess air, but is not on computer control. A computer is available in the unit which could be used.



An annual savings of  $7.5 - 11 \times 10^{10}$  BTU/yr or 2-3% of the total energy consumed in the process can be realized using one preheating scheme [PRE-74, 4-20].

The following are estimates of total energy savings in the refining process:

	% of Total
General - Good Housekeeping, better operation of columns	5.0%
Capital investment measures	
Process Heaters	17.0%
Preheat Crude Train	<u>2.5%</u>
Total	24.5%

With the above estimates the specific energy will be reduced to 0.81 M BTU/ton.

Most energy in a refinery is derived from the combustion of fuels. On an industry-wide basis, combustion operations are 72.8% efficient. The upper limit on achievable combustion efficiencies is 90%. This indicates that combustion efficiencies can be improved 19.3% with a savings of  $1.56 \times 10^{14}$  BTU/yr based on 1973 energy consumption in Texas refineries alone. [PRE-7-,4-22]

An estimated 5-10% reduction in energy consumption can be obtained by good housekeeping measures previously mentioned. The capital investment measures will require several years before savings can be realized. [PRE-74, 4-22]

The present specific energy consumption can be reduced 30.1% of its present value ( $3.5 \times 10^6$  BTU/ton input) to  $2.45 \times 10^6$  BTU/ton input. The combustion losses were obtained from process heaters evaluated throughout industries in Texas. The average combustion efficiency of 72.8% was applied to obtain the process heat and electric generation values. There are inefficiencies in the refining process and electric generation excluding combustion which are included in parts b and c under combustion in Table E.5.4.1-1. [PRE-74,4-24]

The present savings in specific energy consumption (SEC) is composed of capital and non-capital energy saving methods. Table E.5.4.1-1 gives the percent savings in SEC due to capital and non-capital investments. The SEC values can be reduced 17.7% by capital investment and 1% by better operation and maintenance of combustion units. [PRE-74,4-24]

TABLE E.5.4.1-1.  
ENERGY CONSERVATION POTENTIAL. [PRE-74, 4-24]

Items -- In Order of Magnitude (and Priority)	% of Total Energy Use	Estimated % Savings in SEC	Qualification
1. Combustion	97.0		
a. Process Heat	61.7	10.0	{ 7.5% good housekeeping 2.5% capital investment
Direct - 43.6%			
Steam - 18.1%			
(Goes into process operations)			
b. Losses	27.4	18.7	{ 17.7% capital investment 1% good housekeeping
c. Electric Generation	10.9	1.1	
2. Purchased Electric Power Consumption	3.0	.3	{ .03% good housekeeping .27% capital investment
	100.0	30.1	

Estimated reduction can be achieved in approximately 6.6 years, implemented as follows in Texas:

1. Immediate reduction	8.63%
2. In 1.5 years	6.00%
3. Next 5.1 years, 3% reduction for each year	<u>15.47%</u>
	30.1%

The process heat used in the refinery unit operations can be conserved by good housekeeping measures to reduce the SEC by 7.5% and capital investment reducing the SEC by 2.5% in the case study would be typical. Good housekeeping in the operation of turbines for electric power generation and better maintenance of electric drives can reduce the SEC by .03%. Capital investment in improved turbines and electric drives would reduce SEC by 0.27% [PRE-74,4]. Table E.5.4.1-2 shows the demand and energy growth predicted by Prengle for Texas.

The non-capital investment measures can be implemented immediately. The greatest energy saving, mainly due to waste heat recovery, purchasing greater heat transfer area, and greater preheating of streams can be implemented in 1-1/2 years (planning and construction). The other capital investments will take longer and an estimate of 3% per year based on 1973 value could be saved by these measures [PRE-74, 4-25].

#### Power Generation vs. Purchased Power

A variation was found in the trends to buy power or generate it in the refineries in Texas. Energy savings can be achieved by combining power generation with process heating. In this case the turbine operating conditions will be determined by the process in order to fully utilize the exhaust steam. In processes where low pressure steam is utilized, this scheme is most attractive. Another arrangement is the use of gas turbines to generate power combined with waste-heat steam generation. Figure E.5.4.1-1 illustrates the comparison between power plant efficiency and a near optimum refinery cycle. The refinery cycle has an efficiency of 76% while the power plant overall efficiency is 23%. [PRE-74, 4-16].

In some cases the substitution of steam turbine drives for electrical drives has been more economical. Condensing turbines using low pressure steam are more economical than electric motors. Condensing turbines can utilize steam produced from waste heat recovery procedures [PRE-74, 4-16].

#### Other Considerations

A major consideration is the operation of a refinery at reduced capacities. Fuel consumption may rise considerably with reduced plant levels of 10-25%. To minimize this, the trend will be to install multiple units rather than the operation of large units at reduced capacity. In the case of mechanical drives, two units may be installed and one will be shut down at reduced capacity operations.

TABLE E.5.4.1-2.

## DEMAND &amp; ENERGY GROWTH [PRE-74, 4-25]

	1973	1974	1980	1985
1) Demand (tons)	$81 \times 10^6$	$84 \times 10^6$	$122 \times 10^6$	$166 \times 10^6$
2) Energy Consumption (Btu)	$1.3 \times 10^{15}$	$1.35 \times 10^{15}$	$1.39 \times 10^{15}$	$1.84 \times 10^{15}$
3) Specific Energy Consumption (SEC) MBtu/ton	16.1	16.1	11.8	11.1

Basis: Year 1974

Product Demand Growth Rate to 1980 6.4%Product Demand Growth Rate to 1985 6.4%Energy Demand Growth Rate to 1980 .5%Energy Demand Growth Rate to 1985 2.8%

$$0.301 \times \frac{11.8 \times 10^6 \text{ BTU}}{\text{ton}} \times 122 \times 10^6 = 0.43 \text{ quads saved in 1980 in Texas}$$

Estimated Savings

$$0.301 \times 11.1 \times 10^6 \times 166 \times 10^6 = 0.55 \text{ quads in 1985}$$

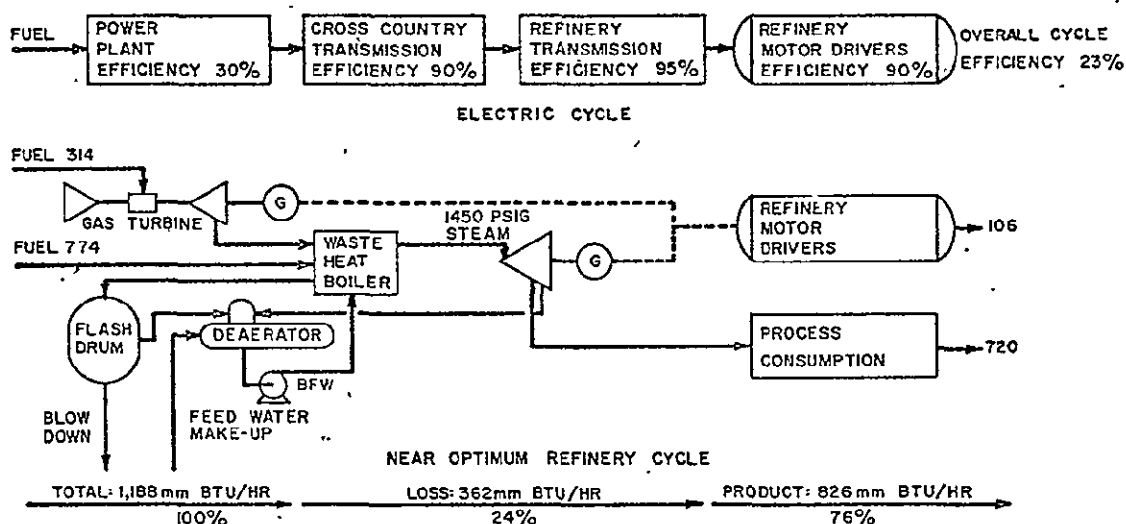


FIGURE 5.4.1-1. COMPARISON BETWEEN NEAR OPTIMUM ENERGY CYCLE FOR A REFINERY WITH A TYPICAL ELECTRIC CYCLE. [PRE-74,4-15]

Of prime importance is the design of new and more effective catalysts. Since catalytic related operations have become so important in the refining of crude oil, more emphasis should be placed on improving catalysts [PRE-74, 4-16].

Domestic petroleum import policy is extremely important in this area. If the U. S. adopts a policy which discourages imports of refined products, it could have a significant impact on the number and configuration of new refineries. Such a policy would encourage the development of refinery capacity which more closely parallels domestic demand for refined products. This would imply a reversal of the trend toward increasing light product yields in favor of additional heavy oil production.

A second factor which relates to the U. S. import policy is the composition of crude oils which will be processed by domestic refineries. Processing heavier crude oils such as those imported from Venezuela can require up to 20 percent more energy than lighter crudes. In general, the crude oils purchased from the Middle East and Africa are lighter and lower in sulfur content than domestic crude oils. A shift away from these lighter crudes may lead to an increase in process energy requirements, provided that the supplemental crude supplies have a higher specific gravity and sulfur content.

Better instrumentation and computer control will improve energy use (NASA technology). Good instrumentation must be available to obtain operating data on a process before major energy conservation measures can be properly analyzed. Computer control can be applied to crude distillation in order to optimize product recoveries as well as in the combustion process.

There is a limited amount of information on the economics of energy conservation within the refining industry, but a summary of a Shell Oil Company study is illustrative. Shell Oil Company undertook a comprehensive energy conservation program starting in mid 1972. This program considered all aspects of their production refining and marketing operations. With regard to refining, Shell set a goal of 10 percent energy savings in four years based on 1971 total usage. Within the first year and a half of the program they had achieved 60% of their goal.

Shell's refinery energy conservation program included both capital and noncapital savings. The percentage savings in the first year and a half were fairly equally divided between the capital and noncapital projects. Major capital projects and estimated energy savings are outlined below:

Shell Energy Conservation Program  
Major Capital Expenditures [EEA-74, 4-23]

1. Direct fired heater performance
  - a. convection section revisions  
Savings: 400,000 barrels per year ( $2.2 \times 10^{12}$  BTU)
  - b. Installation of electronic furnace optimizers  
Savings: 100,000 barrels per year ( $5.5 \times 10^{11}$  BTU)
2. Electrical System
  - a. installation of flux gas expanders in fluid catalytic cracking units  
Savings: 382,000 barrels per year ( $2.0 \times 10^{12}$  BTU)
  - b. installation of hydraulic turbines to recover power from liquid streams  
Savings: 124,000 barrels per year ( $6.8 \times 10^{11}$  BTU)
3. Vapor Recovery
  - a. installation of floating roofs in tanks  
Savings: 85,000 barrels per year ( $4.7 \times 10^{11}$  BTU)
4. Total Energy Savings  
Savings: 1,091,000 barrels per year ( $6.0 \times 10^{12}$  BTU)  
Savings as percent of total consumption: 6%

---

In general, all the measures undertaken by Shell with the exception of floating roofs on storage tanks provided for less than a two year payback period. Therefore, based on the estimated savings of roughly 1.1 million barrels ( $6.0 \times 10^{12}$  BTU) the total capital cost of these projects was less than \$10 million. Assuming that similar savings could be achieved by other refiners using these techniques the total capital cost to the industry would be somewhere in the neighborhood of \$100 to \$150 million dollars. This calculation is based on the fact that Shell owns approximately 8% of U. S. refining capacity [EEA-74, 4-24]. These calculations were based on 1972-73 energy prices. Assuming that other refineries could obtain similar savings, the total saving for refineries instituting these conservation measures could be approximately  $7.5 \times 10^{13}$  BTU.

#### E.5.4.2 FOOD AND KINDRED PRODUCTS

The EEA report made no recommendations as to the potential for conservation in the food processing area other than noting the suggestions by some people that government regulations dealing with food processing be relaxed to some degree. However, such an action must be carefully evaluated before it is implemented.

The installation of Templifiers (heat pumps) to utilize waste heat is one conservation action that has been proposed by Westinghouse [WEST-75,C-4]. According to the report, in the food industry, temperature requirements of processes served by fossil fuels are:

<u>Temperature (°F)</u>	<u>% of Fuel</u>
<230	61
231 - 400	22
>400	6
Space Heat & Misc.	13

Energy substitutions by 2000 are as follows:

- 33% of under 230°F needs supplied by Templifiers (COP=6)
- 45% of 231-400°F needs supplied by Templifiers (COP=3)
- 10% of industry fossil fuels (baking, etc.) shifted to electric  
(Electric at 100% increase in end-use efficiency)
- 25% of industry fossil fuels shifted to electric boilers  
(Electric at 95% efficiency)
- 30% of industry fossil fuels shifted to coal (in 1972, Coal consumption was 14% of Fossil fuel consumption)

Using the data supplied by Westinghouse, the energy that can be saved by installing Templifiers (heat pumps) to utilize some of the waste heat in the food industry is about 0.18 quads. This energy saving was determined by using the following calculation:

$$\frac{10}{25} (.33) (1.439) (.61) = .12$$

$\frac{10}{25}$  converting the time frame from 25 years to 10 years (1985 rather than 2000)

.33 Westinghouse's estimated substitution of Templifiers in processes under 230°F

1.439 total energy use projected for the food industry in 1985.

.61 percentage of fuel in the <230°F range

$$\frac{10}{25} (.45) (1.439) (.22) = 0.06 \text{ in the 231-400 temperature range}$$

$$.12 + .06 = 0.18 \text{ quads in 1985}$$

Approximately 316 thousand barrels of petroleum per day ( $1.74 \times 10^{12}$  BTU/day or 0.6 quads/year) were consumed in the area of farm equipment in 1972 [NPC-74, 90]. With regard to the saving of fuel in this area, the implementation of improved energy management and induced tillage practices have a combined potential of saving 23,000 barrels/day (0.04 quads/yr) in 1978 [NPC-74, 90].

#### E.5.4.3. PAPER

This section lists several actions that can be taken in the paper industry to reduce energy consumption. The actions are broken down into three classifications: (1) good housekeeping, (2) improve combustion efficiency, and (3) process improvements.

The EEA study estimates that more than 10% energy savings can be achieved by good housekeeping measures by 1975 as compared to 1972 figures. The industry energy usage was  $39.9 \times 10^6$  BTU/ton in 1972, and the production was 59.5 tons. [EEA-74, 2-12].

Increase recovery in waste heat boilers of fuel equivalent in bark and spent-pulp liquor; the 1967 industry average can be improved by at least 25%, from  $14.5 \times 10^6$  to  $18.0 \times 10^6$  BTU per ton of paper [PFE-74,62].

Most conservation actions can be classified as process improvements. Below is a list of selected actions along with the source of the information:

Exploit all opportunities to produce electricity prior to generating low-temperature process steam, and sell surplus electricity to utilities [PFE-74, 62].

Increase recycling of waste paper. The industry trend throughout the 1960's was toward less recycling, even though recycled paper requires less than 1/4 as much fuel as paper made from raw wood products [PRE-74,62].

Incorporate paper-forming processes which require less fuel for drying; specifically, Thermo Electron's Lodding K-Former<sup>23</sup> can reduce the water throughput by as much as a factor of 4, and the fuel demand of the paper-making phase of production by 55%. Most of the saving is due to the reduced drying requirements that result because of less stratification in the wet sheet -- more water can be pressed from the sheet prior to entering the dryer section [PFE-74,61].

Increase the integration of pulping and paper-making operations to eliminate fuel used for pulp drying prior to shipment from the pulp mill to the paper mill, which requires  $3.4 \times 10^6$  BTU per ton of pulp dried [PFE-74,61].



Increase use of continuous rather than batch digesters. Continuous digesters reduce fuel consumption by  $1.3 \times 10^6$  BTU per ton [PFE-74,61].

Improvement of techniques and practices which decrease broke (unusable paper), minimization of grade changes on the paper making machines and increase in pulp yields [NPC-74,42].

Avoidance of over drying paper (a 1% decrease in moisture content at the dry end of the paper machine can require almost 3% more steam) [NPC-74,42].

Increased effectiveness of the press section (a 1% average decrease in moisture delivered to the dryers by the press section can be achieved by various control methods and/or press improvements. Because moisture level is on the order of 60% at this point, net steam savings is upwards of 5% of the steam used in the dryers.) [NPC-74,42].

Use of hot exhaust air from gas turbines for paper drying [NPC-74,42].

Increasing the use of wood refuse and other solid wastes as fuels [NPC-74,42].

Improvement of water pollution abatement procedures. (This can mean substantial savings of heat if approached via reduction of fresh water usage through recycling and can achieve plantwide steam savings of up to 10%.) [NPC-74,42].

Improvement of process ventilation methods (for example, the closed paper machine hood achieves a 5-10% steam saving by using less air to vent the evaporated moisture. In cold climates, the elevated temperatures which result from closing the hood present an opportunity for heat reclamation by economizers and result in even greater savings.) [NPC-74,42].

The cumulative effect of implementing various conservation actions in the paper industry is summarized in Table E.5.4.3-1.

#### E.5.5 CONSERVATION ACTIONS

The section is intended to provide a general noninclusive list of conservation actions that have been proposed by various individuals and organizations. Some of the actions are very general while others are quite specific and apply to only one or two industries. No ranking of these actions is intended.

TABLE E.5.4.3-1. CUMULATIVE EFFECT OF CONSERVATION  
MEASURES ON TOTAL FUEL USAGE IN PAPER AND ALLIED PRODUCTS 1971-1990  
[EEA-74,2-27]

Measure \ Year	Decrease from 1971 I/O Coefficient (40 MMBTU/T)									
	<u>Estimated</u>					<u>Projected</u>				
	<u>71/72</u>		<u>73/75</u>		<u>76/80</u>		<u>81/85</u>		<u>86/90</u>	
	<u>MMBTU</u>	<u>%</u>	<u>MMBTU</u>	<u>%</u>	<u>MMBTU</u>	<u>%</u>	<u>MMBTU</u>	<u>%</u>	<u>MMBTU</u>	<u>%</u>
Housekeeping	2.9	7.25	6.1	15.25	6.4	16.00	6.4	16.0	6.4	16.0
Process Improvement	0.5	1.25	1.0	2.50	2.0	5.00	3.0	7.5	4.0	10.0
Integrated Shift	.3	.75	1.0	2.50	1.7	4.25	2.6	6.5	3.0	7.5
Best Practical Control	0.0	0.00	0.0	0.00	-.4	-1.00	-.4	-1.0	-.4	-1.0

Combine generation of steam and electricity  
Increase recuperation for all combustion  
Develop industrial energy engineering  
Fix or maintain steam traps  
Beneficiate ores  
Substitute fuels  
Recycle materials  
Reduce sensible heat loss  
Use by-product gases to replace natural gas  
Use continuous casting methods  
Eliminate reheating  
Replace oversized motors  
Minimize make-up air  
Clean heat transfer surfaces  
Minimize air pressure  
Shut down equipment not in use  
Eliminate energy use over off-times  
Apply peak demand controls  
Increase combustion efficiency  
Reduce steam losses  
Increase heat exchange between processes  
Reduce drying requirements  
Increase integration of operations  
Recycle materials  
Alternative processes  
Oxygen enrichment of air feed  
Reduce current density

Place burners in regions of endothermic reactions

Change the product mix

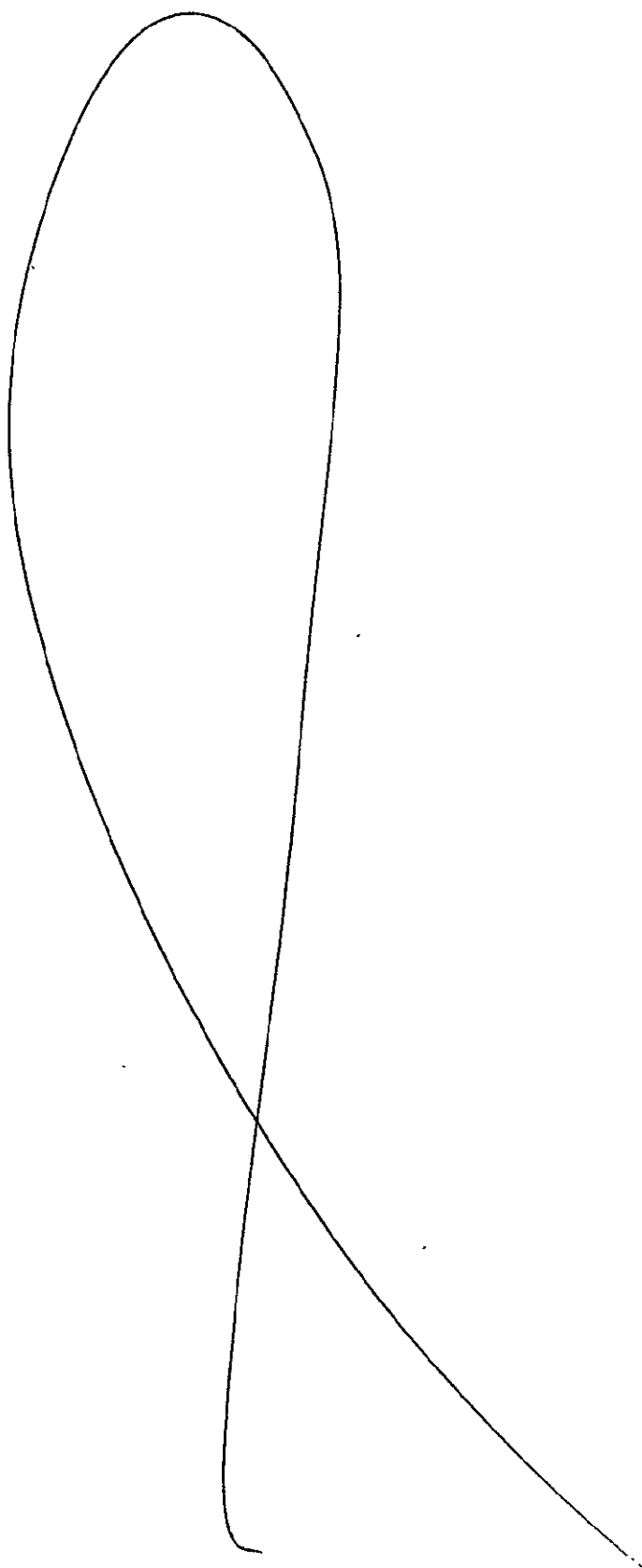
Improve operating and maintenance

Monitor energy

Keep insulation repaired

Reduce excess air feed

Investments in energy conservation hardware



## APPENDIX F. A STUDY OF ENERGY CONSERVATION IN THE TRANSPORTATION SECTOR

Chapter 6 of this report presented background to this subject and a summary of the results. This Appendix has been written to convey in somewhat more detail the methodology that was used in arriving at the results. Also, this Appendix lists all actions, illustrates how the specific ones were selected for study, and tabulates the assessment results. At the end of this Appendix, some energy envelope curves are presented and discussed, and a view toward the future in transportation is offered.

### F.1 METHOD ADOPTED

The systems analysis approach was adopted. Consequently, those steps that were essential to the study were first identified.

A basic objective to our study

The requirements to meet the objective

General constraints and criteria of importance

Those general means by which energy conservation can occur

A list of energy conservation actions, and classification of these actions

A few methods of assessing the impact of these actions

Comparison of the actions with the general constraints and criteria permitted the list to be reduced considerably. Completion of this process was followed by an impact assessment.

A systems analysis diagram is shown in Figure F.1-1. The diagram combines aspects of a system analysis diagram and that of a computer flow chart. Further, it emphasizes the important difference between actions and the implementation of these actions. It is well recognized that many actions could be adopted. The diagram illustrates that worthwhile actions are first identified through assessment; the means by which these are to be implemented should next be sought. This aspect of the study is quite important, and it is likely that sub-sets of seemingly valuable actions must be assessed together before a decision as to a plan of action is determined. Viewed in this manner, Figure F.1-1 represents not only a systems analysis diagram, but it also represents a flow chart of milestones that must be accomplished to reach the goal. At various stages along the way, it was necessary to iterate these steps.

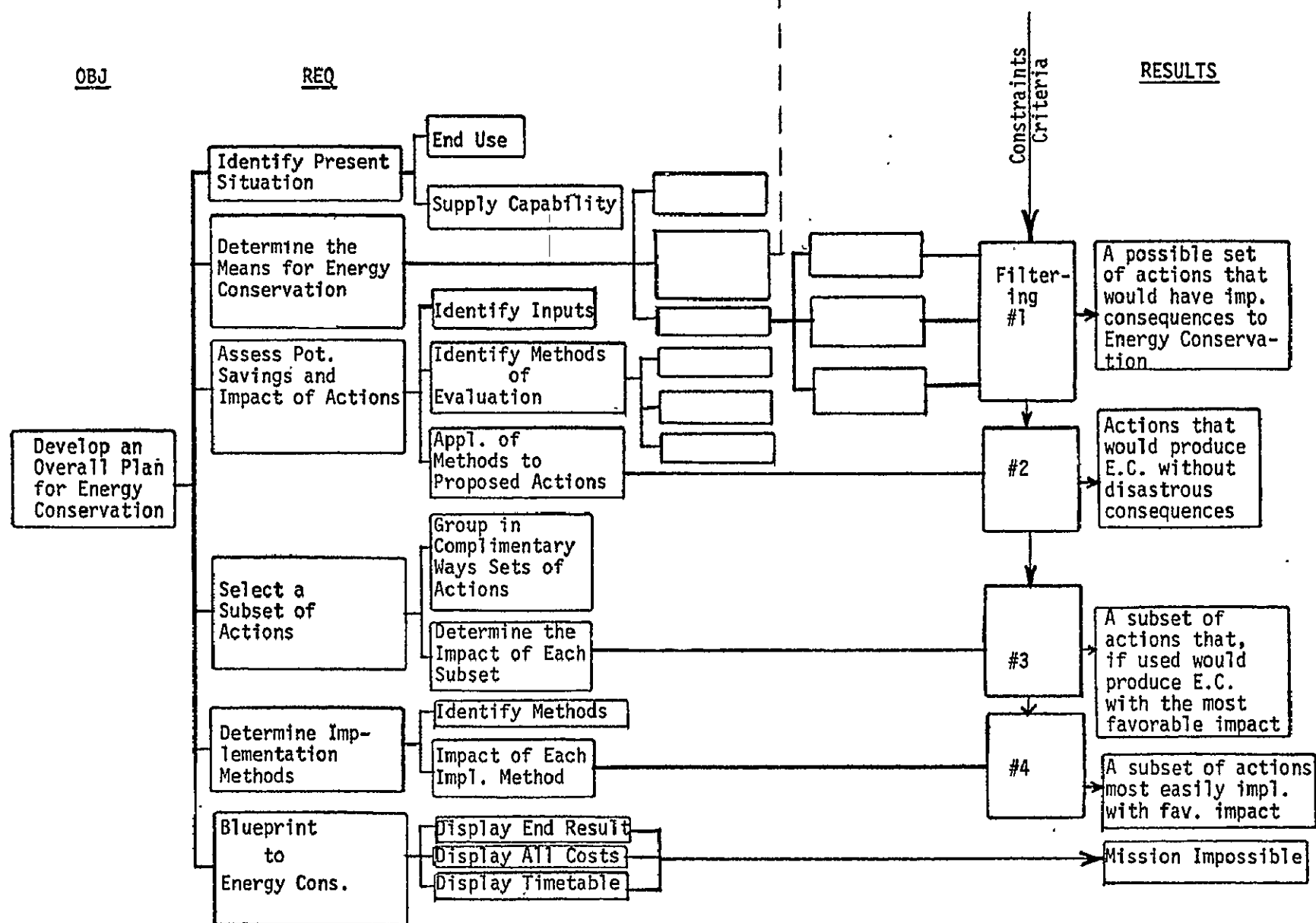


FIGURE F.1-1 SYSTEMS ANALYSIS DIAGRAM FOR THE TRANSPORTATION SECTOR

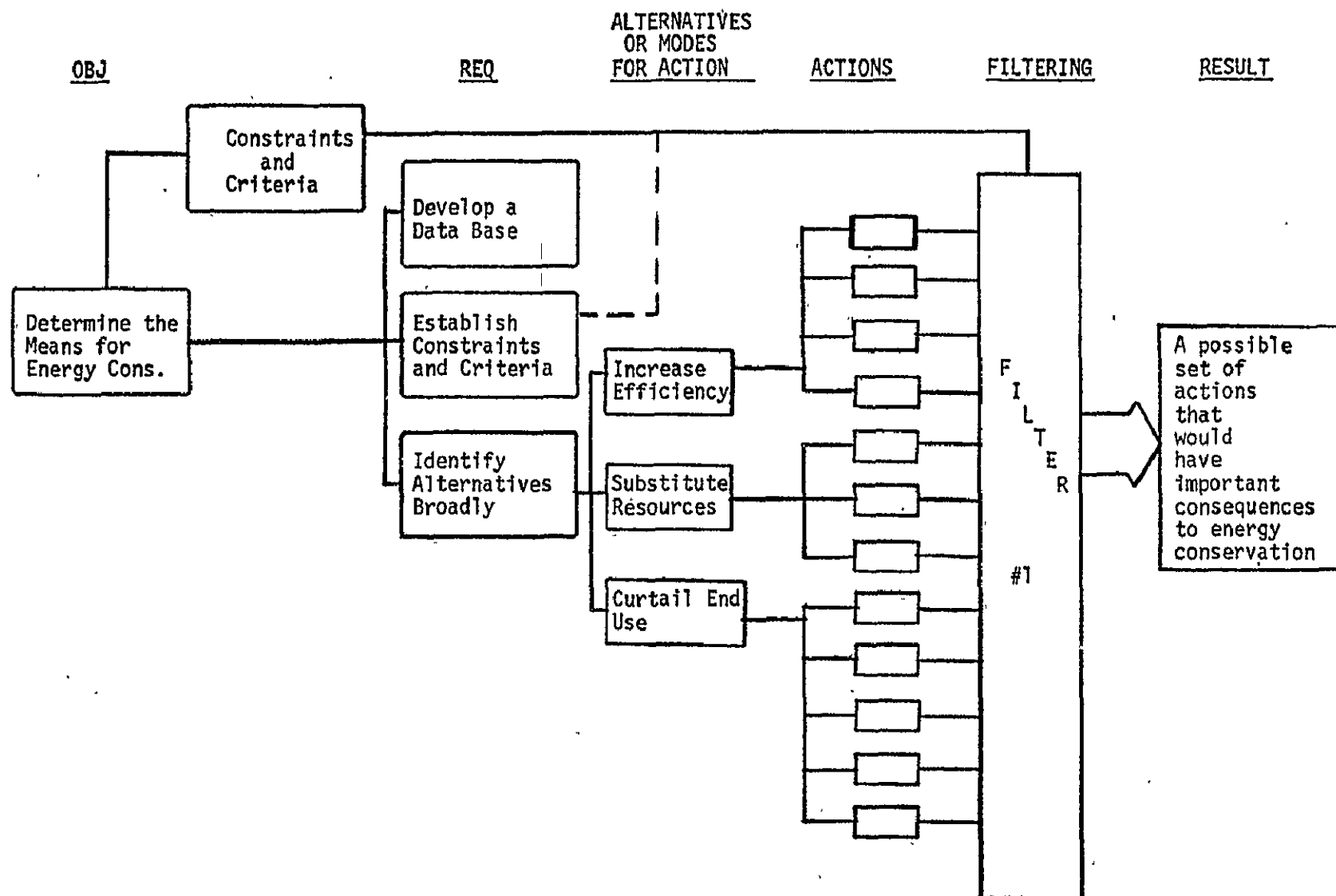


FIGURE F.1-1 (CONTINUED) SYSTEMS ANALYSIS DIAGRAM FOR THE TRANSPORTATION SECTOR



The systems block diagram represents a graphical portrayal of a determination process wherein items are conceived, evaluated, selected, re-evaluated and then accepted or rejected. Specifically, a conceived action that will perform the required function, satisfy the listed constraints, meet the selection criteria, and produce no unacceptable impacts becomes a viable candidate. The number of adoptions becomes a function of the number desired plus the outcome of a comparison process (trade-off) wherein their relative merits are examined and arrayed.

## F.2. CONSTRAINTS AND CRITERIA

It is evident that in a broad study of this sort, both specific constraints and criteria evolve as the study progresses. The design group identified a general list of constraints and criteria; then the transportation task force further clarified these for its evaluation purposes. It is rather important to recognize that some of these constraints can, in fact, be altered. Table F.2-1 shows that most of the constraints discussed presently are variable, and this is particularly true if one considers that an attempt is being made to consider the next 25-year period -- if not longer. It is evident that, at each level of the assessment procedure, both the constraints and criteria must be reexamined, perhaps revised, and may be made more specific.

Criteria have been adopted earlier in the report, and the transportation sector group used them in assessing proposed actions. The very first -- that of reducing dependence on non-domestic energy -- is of major importance. It has previously been pointed out that 95% of all transportation energy is presently derived from petroleum and natural gas. Since the transportation sector uses 40% of all petroleum, it is imperative that the transportation sector should strive to use the supply wisely and to curtail its use where possible.

Consider the second criteria: Will the proposed action have minimum or desirable environmental impact? It is already well recognized that transportation modes play a very important role in the environment. Additionally, efforts to eliminate pollutants have been at odds with the need to save energy. Each new engine possibility must be weighed from both standpoints.

## F.3 POSSIBLE ENERGY CONSERVATION ACTIONS IN THE TRANSPORTATION SECTOR AND THEIR POTENTIAL

A listing of approximately two hundred energy conservation actions has been identified and compiled. The list is far from complete; yet, it is representative of the types of actions which are often suggested. The intent here is to present those which were considered and to present the methods used to initially filter the list. In order to evaluate these actions, they were first listed and then grouped based upon two classification schemes.

---

TABLE F.2-1 MODIFICATION OF THE CONSTRAINTS FOR USE IN THE  
TRANSPORTATION SECTOR

---

<u>Category</u>	<u>Classification</u>
1. Political	
Written Laws	Variable
Popularity Indicators	Variable
Strategic Posture	Relatively fixed
Foreign Relations	Relatively fixed
2. Economic Constraints	
Capital Available to Each Mode	Variable
Personal Expenditures for Transportation (% of Income)	Variable
3. Technological Constraints	
Limits of Development (Relatively smooth changes in the state-of- the art)	Relatively fixed
Physical Laws	Unalterable
Implementation Time Frame	Variable
4. Social	
Population Growth	Self-imposed, Fixed
Must Consider All Groups of Persons	Self-imposed, Fixed
5. Available Resources	
Level of Fossil Fuel Available	Variable
Manpower Availability	Variable
Construction Material Availability	Variable
Overall Capital Available to the Transportation Sector	Variable

---

The first of these classification techniques is based upon the primary means to achieve energy conservation: improved system efficiency, substitution for scarce energy resources, and curtailment of end use. The categories were further subdivided, and all proposed actions placed within one of them.

The second method of classification is simply one based upon the concept of a macro system (operational) and a micro system (design). For example, an increase in rail freight transport to obtain an improved system efficiency would be classified as a part of the macro system. On the other hand, an improvement in train engine efficiency would be classified as an action within the micro system. Both classifications are presented in Table F.3-1; macro classifications are indicated with an O, and micro classifications are indicated by an S. There are other methods of classification of these actions (for example, by mode); however, these have not been used.

Each action in Table F.3-1 was examined and qualitatively assessed by members of the group. This initial assessment represented a quick evaluation based on three items:

Energy conservation potential

Ease of implementation

Public acceptance

Compilation of the results showed that about thirty-five actions were highly rated. However, most of these appeared in one classification area -- that of improving system efficiency.

An attempt to broaden the listing was made by requesting from each group member those major items that were thought to be important. Again, the list was primarily restricted to the single area, though not exclusively. In hindsight, it seems reasonable that the group's high ratings of the system efficiency area were a result of each group member's background. (All members attempted to solve the problem by providing a technical solution.) The importance of this discussion is the recognition of the need to involve individuals with a wide range of backgrounds in addressing problems of this sort. Even now, a haunting question remains concerning the selection of persons to engage in a systems analysis of the problem.

A very interesting, grand experiment would be to formulate a major problem area, and then ask two independent groups to perform a systems analysis of the problem. Each group would be presented the same information, the same speakers, etc. Working in the same time frame, the groups would be asked to present a report summarizing their own solutions to the problem. These solutions should then be carefully compared to establish the common ground between the two reports.

TABLE F-3-1 CLASSIFICATION OF ACTIONS

I. Improve System Efficiency	Mode
A. By means of a better mix of modes	
1. Provide transport centers linked to urban centers	0
2. Improve personal service at transit stations	0
3. Reduce travel time of public carriers	0
4. Provide listening stations, coffee availability	0
5. Provide hostess service	0
6. Permit airlines to operate Amtrak routes	0
7. Encourage auto companies to build railroad cars, buses, and new trucks	0
8. Provide unions with a voice in solving transportation problems	0
9. Eliminate duplicate transportation systems	0
10. Use pipelines for transporting goods	S
11. Transport people by capsule	S
12. Use a mix of conveyances that are more efficient	0
13. Use modes of transport that provide integrated service	0
14. Integrate truck and rail freight services	0
15. Shift highway trust funds to UMTA	0
16. Subsidize mass transit even more than at present	0
17. Provide mass transit income tax deduction	0
18. Ride a bus at least 1 day/week	0
19. Establish exclusive bus lanes	0
20. Use school buses and city buses interchangeably	0
21. Promote riding by train or bus	0
22. Regulatory agency changes to shift freight from truck to rail	0
23. Shift pricing to encourage use of trains and buses	0
24. Shift industrial schedule to use fewer personal transit modes	0
25. Form carpools	0
26. Encourage industrial carpooling	0
27. Eliminate overtime to encourage carpools	0
28. Use Swiss type aero busses (cable suspended)	S
29. Use piggy back truck system to transport people	0
30. Ship by rail rather than truck	0
31. Nationalize the railroads	0
32. Use interstate right-of-way for improved Amtrak service	0
33. Optimize air routes	0
34. Retire corporate jets and use commercial flights	0
35. Increase freight travel by water	0
36. Free water freight from legal restrictions	0
B. Regulatory policy	
1. Establish a state transport authority	0
2. Eliminate ICC freight barriers	0
3. Straighten railroad lines, and improve roadbed	0
4. Establish a 55 mph speed limit	0
5. Improve urban traffic flow	0
6. Improve driving habits of government employees	0
7. Operate aircraft at optimum long-range cruise power	0
8. Have frequent auto tune-ups	S
9. Develop efficiency standards	S
10. Label energy consuming vehicles	S
11. Use life cycle energy cost analysis for purchasing decisions	0
12. Purchase diesel powered cars	0
13. Buy high efficiency engines, diesel, or other	0
14. Encourage churches and similar groups to buy and operate buses for their members	0

ORIGINAL PAGE IS  
OF POOR QUALITY

TABLE F.3-1 CLASSIFICATION OF ACTIONS (CONT'D)

	Mode
<b>C. Technological improvement</b>	
1. Award efficient vehicle designs	S
2. Replace inefficient vehicles with eff. ones	S
3. Develop lighter weight vehicles	S
4. Design for longer life and maintainability	S
5. Use improved air conditioning systems in vehicles	S
6. Improve conventional engines	S
7. Use Stirling cycle engines	S
8. Use of Gas Turbines	S
9. Use Stratified charge engines	S
10. Use Rotary engines	S
11. Use Diesel engines	S
12. Use Warren engine	S
13. Remove emission controls	S
14. Use external combustion engines	S
15. Use Steam engines	S
16. Consider frequency of oil changes	S
17. Reduce the capacity of gas tanks on new vehicles	S
18. Use higher eff. transmission	S
19. Allow free wheel drive options	S
20. Provide overdrive as an option on vehicles	S
21. Match engines and transmission	S
22. Use regenerative braking	S
23. Use energy storage devices	S
24. Provide regenerative battery storage	S
25. Develop tires with reduced rolling friction	S
26. Use radial tires on all vehicles	S
27. Better aerodynamic designs for all vehicles	S
28. Streamline trucks	S
29. More efficient packaging of freight goods	O
30. Use container standards	O
31. Provide tax credits on energy saved	O
32. Standardize truck design and load requirements	S
33. Provide gas turbines for trains and trucks	S
34. Improve barge shapes	S
35. Aircraft should use tail winds when possible	O
36. Use larger pipe diameters for pipelines	S
37. Pump LNG across country	S
38. Slow pumping velocities in pipelines	O
40. Set speed limits to take advantage of best operating efficiency	O
<b>II. Substitution for Scarce Energy Resources</b>	
<b>A. Electrification</b>	
1. Develop and use electric automobiles	S
2. Ensure government purchases electric vehicles for urban use	S
3. Electric driven cable cars	S
4. Use of personalized transport systems	S
<b>B. Alternate fuels</b>	
1. Hydrogen as an automotive fuel	S
2. Methanol as an automotive fuel	S
3. Ammonia as an automotive fuel	S
4. Metal hydrides	S
<b>C. Conveyor transport</b>	
1. Moving sidewalks	S
2. Transport of purchases by conveyor	S
3. Chain driven street traffic	S

TABLE F.3-1 CLASSIFICATION OF ACTIONS (CONT'd)

	Mode
D. Use of manpower	
1. Support bikeway program	0
2. Tax deduction for bicycle purchase	0
3. Tax credits and incentives for those who use bicycles	0
4. Use skates in warehouses	S
5. Institute a safe travel system for hitch-hiking	0
6. Walk, rather than drive	0
E. Recycle transportation products and devices	
1. Reprocess old vehicles	0
2. Subsidize system for collecting and reprocessing tires, batteries, and parts	0
3. Recycle lubrication oils	0
4. Give freight incentives to secondary and recycled material transport	0
III. Curtailment of End Use	
A. Regulatory Policy	
1. Support EPA transportation control plan	0
2. Odd-even gas fill-up days	0
3. Use traditional dates for holidays	0
4. Discourage long auto trips	0
5. Raise minimum driving age to 18	0
6. Curtail Sunday driving from 1:00 p.m. to midnight	0
7. Require strong justification for all "business travel"	0
8. Reduce non-essential military travel	0
9. Ban all speed races	0
10. Severely reduce government travel, say by 90%	0
11. Close commercial stores on Sundays and holidays	0
12. Increase postage to reduce mail load	0
13. Do not carry any bulk mail	0
14. Establish bulk mail energy tax to reduce Post-Office transportation requirements	0
15. Impose parking restrictions in downtown areas	0
16. Use fringe parking facilities for urban areas	0
17. Vary parking charges according to load to encourage pooling	0
18. Set by law the size of private vehicles	0
19. Limit advertising of energy-wasting consumer products and travel	0
20. Issue ration coupons to autos	0
21. Issue ration coupons to truckers	0
22. Use a sliding scale based upon importance of use to determine rationed amounts	0
23. Ration each of the major carriers by the fraction of total freight carried	0
24. Require an "energy program" as a part of purchase considerations by the government (to include energy manager, program to show design, production, and purchase emphasis)	0
25. Require government to make vehicle purchases on basis of the sum of the lowest purchase price and estimated fuel costs for 10-year lifetime	0
26. Require energy cost/benefit analysis as part of all government contracts	0
27. Produce more durable vehicles	S
28. Provide off-peak pricing for busses and taxis	0
29. Regulate licensing fee according to displacement and fuel efficiency	0
30. Develop a scaled gasoline tax to increase geometrically after an allotted use	0
31. Impose taxes on autos as a function of their ability to conserve energy	S
32. Impose higher taxation on larger, heavier vehicles	S
33. Encourage increased license taxation on inefficient automobiles by state	S

ORIGINAL PAGE IS  
OF POOR QUALITY

TABLE F.3-1 CLASSIFICATION OF ACTIONS (CONT'D)

	Mode
34. Impose a special tax on recreational vehicles, pleasure boats, trailers, private and non-business aircraft	0
35. Tax energy consuming accessories	0
36. Increase and/or impose taxes on downtown parking areas	0
37. Tax dead heading of trucks, rail cars	0
38. Impose transport taxes on all fuels, particularly high ones on gasoline	S
39. Impose taxation on all vehicles from outside of a region, as defined by the Census Bureau	0
40. Cities impose highway use taxes	0
41. Provide a mileage tax credit for proven reduced auto mileage	0
42. Permit accelerated depreciation on industrial and commercial vehicles which are fuel efficient	0
43. Tax credits on all retrofits which reduce energy use	0
44. Terminate federal subsidies for airlines	L
45. Control airline flights more vigorously; increase load factor	0
46. Tax air travel if less than 200 miles	0
47. Establish minimum load factor for licensing of private and/or corporate aircraft	0
48. Eliminate flight pay incentives for officers who do not need to retain their flying skills	0
49. Control airlines movement on ground	0
50. Require labeling of energy to manufacture on all new vehicles	S
B. Managed population growth rate.	
1. Promote planned parenthood	0
2. Do not allow any more immigration	0
3. Provide birth control information at no cost	0
4. Educate all citizens concerning population	0
5. Cut welfare to families that produce very large families	0
C. Education of all citizens concerning energy conservation	
1. Encourage work at home programs for professional people	0
2. Minimize shopping trips	0
3. Distribute information on tune-ups, good driving trips, etc.	S
4. Provide inspection processes for energy savings	S
5. Promote staggered working hours to reduce travel times	0
6. Encourage motorists to reduce use by 1 gallon/wk.	0
7. Eliminate drive-in services	0
8. Ask people to use elevators only for more than 1 floor up or 2 floors down	0
9. Ask league of Women Voters to spread message of conservation	0
10. Merchandise energy conservation	0
11. Massive public education program	0
D. Alternatives to transportation.	
1. Encourage the use of telecommunications to eliminate travel	0
2. Reduce professional meetings by use of telecommunications and written material	0
3. Transport-communicative trade-off	0
4. Change distribution of news and magazines	0
5. Reduce mailing requirements	0
6. Provide more delivery services of purchased goods	0
7. Promote use of phone and written communication	0
8. Handle more shopping trips and business trips by phones and memo	0

TABLE F.3-1 CLASSIFICATION OF ACTIONS (CONT'D)

	Mode
E. Improved Urban Planning	
1. Develop and publicize local recreation and entertainment possibilities	0
2. Revive recreational ideas which do not use energy	0
3. Locate shopping centers within easy walking distance of neighborhoods	0
4. Provide for right turn on red	0
5. Better coordination of traffic light operations	0
6. Ban traffic in downtown areas	0
7. Ban parking in downtown areas	0
8. Encourage multi-force taxi regulations	0
9. Use off peak pricing for busses and taxis	0
10. Provide express lanes for carpools and busses	0
11. Provide rush hour busses on an optimal service basis	0
12. Optimize bus routes	0
13. Eliminate inefficient bus routes	0
14. Encourage four day work weeks	0
15. Shift to industries that do not require as much transportation energy	0
16. Shift the transportation mode of various industries, e.g. the food industry, etc.	0



In this study, the transportation group eventually conceded that the broad areas of substitution for scarce energy resources, and the curtailment of end use should not be omitted. Through reexamination of the basic list, several actions were identified in each category that might produce some energy savings. These methods finally produced a list of thirty-five actions which were then considered in more detail; this Table is F.3-2 and is also shown in Chapter 6. The next step was to determine the energy savings potential and the basic requirements of each action. These results are included in Section F.4, since they are required as a part of the assessment of actions. In Appendix F.4, a detailed discussion of the methods used to identify and assess the impacts of these actions is presented.

#### F.4 ASSESSMENT OF ACTIONS

Working from the list of actions in Table F.3-2, a three stage assessment, decision making process was employed.

Impact assessment

Decision making

Cross evaluation

##### Impact Assessment

Table F.4-1; Energy Reduction Potential and Requirements, represents the first step in achieving an assessment of these actions. Data within the table have been extracted from the literature, wherever possible. Energy conservation potentials illustrate the maximums stated in the references listed. Drawing heavily on the displays and methodology developed by [Voorhees-74], an impact assessment matrix was developed for portraying in capsule form: (a) Institutional Impacts, (b) Socioeconomic Impacts, and (c) Environmental Impacts. Completed matrices for the above three impact areas are portrayed as Tables F.4-2, F.4-3, and F.4-4, respectively.

Once the various sub-categories of requirements and impacts had been decided upon, the task group, working as a group and drawing upon their individual data bases acquired in the early weeks of this systems study, completed Tables F.4-1 through F.4-4. As an aid in this process, brief definitions for all impacts and requirements were provided and are included immediately following Table F.4-4.

##### Decision Matrix

- The impact assessment matrices Tables F.4-2 through F.4-4 are a concise way of indicating a multitude of impacts, but additional steps are necessary to screen the list of possible actions to a smaller number. Drawing upon the work of [Hill-70], a weighted decision matrix was developed. The completed matrix is given a Table F.4-5.

TABLE F.3-2. ENERGY CONSERVATION ACTIONS IN THE TRANSPORTATION SECTOR

I. Improve System Efficiency

## A. System Operations Improvement

1. Use modes that are inherently more efficient
2. Shift from truck to rail
3. Form carpool
4. Shift passenger traffic from auto to bus and/or rail
5. Use auto-train and/or railroad and airport auto rental
6. Optimize air routes by eliminating short hauls, increasing load factors, and reduction in cruising speed
7. 55 mph speed limit

## B. Technological Improvement

8. Use lighter weight autos
9. Design for prolonged life
10. Stratified charge engine
11. Other improved engine designs  
Stirling cycles, gas turbines, rotary engines, Rankine cycle engines
12. Improved transmissions  
Better matched to engines  
Elimination or improvement of automatic transmissions, or with lock up
13. Hybrid systems (flywheel, hydraulic battery storage, etc.)
14. Improved tires (radials)
15. Aerodynamic improvements

II. Substitution for Scarce Energy Resources

## A. Electrification of Particular Modes

16. Electric automobiles
17. Electrification of railroads and urban buses

## C. Use of Manpower

20. Promote a bikeway program
21. Walk, rather than drive

## B. Alternate Fuels

18. Hydrogen
19. Other fuels (methanol, liquified methane, ammonia, etc.)

## D. Recycle Transportation Products

22. Reprocess wornout transportation vehicles
23. Recycle lubrication oils

III. Curtailment of End Use

## A. Managed Population Growth Rate

24. Promote planned parenthood
25. Reduce immigration into this country

## C. Alternatives to Personal Transportation

29. Use telecommunications to eliminate travel
30. Provide more delivery services of purchased goods

## B. Education of All Citizens

26. Obtain support of groups like League of Women Voters
27. Support public education programs
28. Obtain support of corporations to provide employee incentives

## D. Improved Urban Planning

31. Develop and publicize local recreation and entertainment possibilities
32. Locate shopping centers within walking distance
33. Ban parking in downtown areas

## E. 34. Reduced travel incentives

TABLE F.4-1. ACTIONS TO CONSERVE ENERGY IN THE TRANSPORTATION  
SECTOR: ENERGY REDUCTION POTENTIAL AND REQUIREMENTS

Action Group	Action	Time to Implement	Energy Reduction Potential	Implementation Requirements		
				Cost	Manpower	Materials
I-A	1	M-L	L	L	L	L
	2	N-M	M	S	S	S
	3	N	L	S	S	S
	4	N-M	M	M	M	M
	5	M	M	M	S	M
	6	N-M	M	S	S	S
	7	N	L	S	S	S
I-B	8	N	L	S	S	S
	9	N-M	S	S	S	S
	10	N	M	S	S	S
	11	N-M	M	M	S	S
	12	N	S	S	S	S
	13	M	M	M	S	S
	14	N	M	S	S	S
	15	N	S	S	S	S
II-A	16	M-L	L	M	M	M
	17	M-L	M	M	M	M
II-B	18	M-L	L	L	L	L
	19	M	L	M	M	M
II-C	20	N	S	S	S	S
	21	N	S	S	S	S
II-D	22	N	S	S	S	S
	23	N	S	S	S	S
III-A	24	N-M	M	S	S	S
	25	N	S	S	S	S
III-B	26	N	M	S	S	S
	27	N	M	S	S	S
	28	N	S	S	S	S
III-C	29	M	M	M	S	S
	30	M	M	S	S	S
III-D	31	N	S	M	S	S
	32	M	M	M	M	M
	33	N	M	S	S	S
III-E	34	N	M	S	S	S

TABLE F.4-1 (Cont.). ENERGY CONSERVATION ACTIONS AND APPROPRIATE REFERENCES

Actions		Conservation Potential - Quads	References
IA	1	10 - 25	[Rice-74], [Ford-74], [Krzyczkowski-75], [UMTA-P-74], [DOT Pratt-73]
	2	0.5	[Malliaris-73], [Ford-74], [UMTA-P-74]
	3	0.5 - 1.0	[Malliaris-73], [Voorhees-74]
	4	0.5 - 10.0	[Malliaris-73], [O'Connell-73], [Ford-74]
	5	1.0 - 4.4	[Rice-74]
	6	0.05- 0.3	[Malliaris-73], [Ford-74], [Pilati-74], [Mutch-73]
	7	0.25- 0.5	[Malliaris-73], [Voorhees-74]
IB	8	0.5 - 1.5	[SAE-75], [Malliaris-73], [DOT-EPA-75], [APS-75], [Pierce-75]
	9	0.4	[Berry-73]
	10	1.0 - 3.0	[DOT-EPA-75], [APS-75], [Cohn-75], [Kummer-75], [Pierce-75]
	11	1.0 - 4.0	[Schneider-75], [Kummer-75], [BNA-EUR-75], [Pierce-75], [Malliaris-73]
	12	0.5 - 1.5	[Malliaris-73], [DOT-EPA-75], [APS-75], [Pierce-75]
	13	-	[Beale-74], [Nondahl-75], [Lawson-74]
	14	0.2 - 0.8	[Malliaris-73], [DOT-EPA-75], [APS-75], [Pierce-75]
	15	0.1 - 0.8	[Malliaris-73], [DOT-EPA-75], [APS-75], [Pierce-75]
IIA	16	-	[Malliaris-73]
	17	-	[Mascy-74]
IIB	18	0 - 1.5	[Malliaris-73], [Alexander-75], [Stocky-75], [AGA-72]
	19	-	[Malliaris-73], [Alexander-75]
IIC	20	0.1 - 0.25	[Malliaris-73], [DPD-75], [Voorhees-74]
	21	0.1 - 0.25	[Malliaris-73], [Penner-74]
IID	22	0.1 - 1.2	[SAE-75], [Berry-73], [Hannon-75]

TABLE F.4-1 (Cont.). ENERGY CONSERVATION ACTIONS AND APPROPRIATE REFERENCES

Actions		Conservation Potential - Quads	References
	23	-	[H.R. 7014-75]
IIIA	24	- 2.0	[Holdren-73]
	25	- 0.25	[Ryder-73]
IIIB	26	1.5 - 3.0	
	27	1.5 - 3.0	
	28	- 0.5	
IIIC	29	0.1 - 0.5	[Voorhees-74], [Tyler-74], [Latney-75]
	30	0.1 - 0.25	[Voorhees-74]
IIID	31	0.5 - 1.0	
	32	0.1 - 0.2	[Voorhees-74]
	33	0.1 - 0.25	[Malliaris-73]
IIIE	34	1.0 - 2.0	

TABLE F.4-2 ACTIONS TO CONSERVE ENERGY IN THE TRANSPORTATION  
SECTOR: IMPLEMENTATION CONSIDERATIONS AND INSTITUTIONAL IMPACTS

Action Group	Action	New Legislation Required	Who Is To Administer Action Implementation	Organizational Changes Required	Who Has A Stake In The Actions and Administration	Public Reaction	Enforcement
I-A	1	Yes	P,L,S,F	L	L	+	Yes
	2	Yes	P,F	S	S	+	Yes
	3	No	P	S	M	-	No
	4	Yes	P,L,S,F	S	L	+	Yes
	5	Yes	P,L,F	S	L	+	Yes
	6	Yes	P,L,F	S	M	+	Yes
	7	Yes	L,S,F	S	M	+	Yes
I-B	8	Yes	P,F	S	S	+	Yes
	9	Yes	P,F	S	S	+	Yes
	10	No	P	S	S	+	No
	11	No	P	S	S	+	No
	12	No	P	S	S	+	No
	13	No	P	S	S	+	No
	14	No	P	S	S	+	No
	15	No	P	S	S	+	No
II-A	16	Yes	P,L,S,F	M	L	+	Yes
	17	Yes	P,L,S,F	M	M	+	Yes
II-B	18	Yes	P,L,S,F	M	L	-	Yes
	19	Yes	P,L,S,F	M	M	+	Yes
II-C	20	No	P,L	S	S	+	No
	21	No	P	S	S	0	No
II-D	22	Yes	P,L,F	S	S	+	Yes
	23	Yes	P,F	S	S	+	Yes
III-A	24	Yes	L,S,F	S	M	+	Yes
	25	Yes	F	S	S	+	Yes
III-B	26	No	P	S	S	+	No
	27	Yes	P,L,S,F	S	S	+	Yes
	28	Yes	P,F	S	S	+	Yes
III-C	29	Yes	P,L,S,F	L	L	+	Yes
	30	No	P	S	S	+	No
III-D	31	No	L,S	S	S	+	No
	32	No	L	S	M	+	No
	33	Yes	P,L	S	M	+	Yes
III-E	34	Yes	P,L,S,F	M	M	+	Yes

TABLE F.4-3 ACTIONS TO CONSERVE ENERGY  
IN THE TRANSPORTATION SECTOR: SOCIOECONOMIC EFFECTS

Action Group	Action	Travel Time	Safety	Life Style Changes	Social Equity	Economic Dislocations	Development Opportunities
I-A	1	+	+	LE	Mi	LE	LE
	2	0	+	SE	Mi	SE	SE
	3	+	+	SE	Mi	NE	NE
	4	+	+	SE	Mi	SE	SE
	5	+	+	SE	Mi	SE	SE
	6	0	0	NE	Mi	SE	NE
	7	0	+	NE	Mi	NE	NE
I-B	8	0	-	SE	Mo	SE	SE
	9	0	0	SE	Mi	SE	NE
	10	0	0	NE	Mi	NE	NE
	11	0	0	NE	Mi	NE	NE
	12	0	0	NE	Mi	NE	NE
	13	0	0	NE	Mi	NE	NE
	14	0	+	NE	Mi	NE	NE
II-A	15	0	+	NE	Mi	NE	NE
	16	0	0	SE	Mi	LE	LE
II-B	17	0	+	SE	Mi	SE	SE
	18	0	-	SE	Mi	SE	LE
II-C	19	0	0	SE	Mi	SE	SE
	20	0	-	SE	Mi	NE	NE
II-D	21	-	0	SE	Mo	NE	NE
	22	0	0	SE	Mi	NE	SE
III-A	23	0	0	NE	Mi	NE	NE
	24	0	0	SE	Mo	NE	NE
III-B	25	0	0	NE	Mi	NE	NE
	26	0	+	NE	Mi	NE	NE
III-C	27	0	+	NE	Mi	NE	NE
	28	+	+	NE	Mi	NE	NE
III-D	29	+	+	LE	Mo	LE	LE
	30	0	+	SE	Mi	SE	SE
III-E	31	0	+	SE	Mi	SE	SE
	32	+	+	SE	Mi	SE	SE
	33	0	+	SE	Mi	SE	SE
	34	0	+	SE	Mi	SE	SE

TABLE F.4-4 ACTIONS TO CONSERVE ENERGY  
IN THE TRANSPORTATION SECTOR: ENVIRONMENTAL EFFECTS

Action Group	Action	Air Pollution	Noise Pollution	Traffic Congestion	Land Use Patterns
I-A	1	+	+	+	LE
	2	+	+	+	NE
	3	+	+	+	SE
	4	+	+	+	SE
	5	+	+	+	SE
	6	0	+	-	NE
	7	+	+	0	NE
I-B	8	+	+	+	NE
	9	+	0	0	SE
	10	+	0	0	NE
	11	+	0	0	NE
	12	+	0	0	NE
	13	+	+	0	NE
	14	+	-	0	NE
	15	+	+	0	NE
II-A	16	+	+	0	SE
	17	+	+	+	SE
II-B	18	+	0	0	SE
	19	+	0	0	NE
II-C	20	+	+	+	SE
	21	+	+	+	SE
II-D	22	0	0	0	NE
	23	0	0	0	NE
III-A	24	+	+	+	LE
	25	+	+	+	SE
III-B	26	+	+	+	NE
	27	+	+	+	NE
	28	+	+	+	SE
III-C	29	+	+	+	LE
	30	+	+	+	SE
III-D	31	+	+	+	SE
	32	+	+	+	LE
	33	+	+	+	SE
III-E	34	+	+	+	NE



TABLE F.4.-5. DECISION MATRIX

Actions	Conservation Potential	Institutional Impacts	Socio-Economic Impacts	Environmental Impacts	Total Weighted Score
Weighting Factor	0.4	0.1	0.3	0.2	1.0
1	5 / 2.0	4 / .4	8 / 2.4	8 / 1.6	6.4
2	8 / 3.2	7 / .7	5 / 1.5	4 / .8	6.2
3	10 / 4.0	7 / .7	7 / 2.1	6 / 1.2	8.0
4	6 / 2.4	5 / .5	7 / 2.1	6 / 1.2	6.2
5	6 / 2.4	6 / .6	9 / 2.7	4 / .8	6.5
6	8 / 3.2	6 / .6	5 / 1.5	3 / .6	5.9
7	9 / 3.6	5 / .5	8 / 2.4	5 / 1.0	7.5
8	10 / 4.0	8 / .8	3 / .9	6 / 1.2	6.9
9	7 / 2.8	7 / .7	5 / 1.5	2 / .4	5.4
10	8 / 3.2	10 / 1.0	6 / 1.8	5 / 1.0	7.0
11	7 / 2.8	10 / 1.0	6 / 1.8	4 / .8	6.4
12	7 / 2.8	10 / 1.0	6 / 1.8	3 / .6	6.2
13	8 / 3.2	9 / .9	6 / 1.8	7 / 1.4	7.3
14	8 / 3.2	10 / 1.0	7 / 2.1	3 / .6	6.9
15	7 / 2.8	10 / 1.0	6 / 1.8	4 / .8	6.4
16	7 / 2.8	3 / .3	5 / 1.5	6 / 1.2	5.8
17	5 / 2.0	4 / .4	4 / 1.2	6 / 1.2	4.8
18	4 / 1.6	1 / .1	5 / 1.5	4 / .8	4.0
19	7 / 2.8	3 / .3	5 / 1.5	3 / .6	5.2
20	7 / 2.8	10 / 1.0	5 / 1.5	5 / 1.0	6.3
21	7 / 2.8	8 / .8	4 / 1.2	4 / .8	5.6
22	7 / 2.8	6 / .6	6 / 1.8	1 / .2	5.4
23	7 / 2.8	6 / .6	5 / 1.5	1 / .2	5.1
24	9 / 3.6	5 / .5	4 / 1.2	6 / 1.2	6.5
25	7 / 2.8	7 / .7	6 / 1.8	4 / .8	6.1
26	8 / 3.2	10 / 1.0	7 / 2.1	6 / 1.2	7.5
27	8 / 3.2	6 / .6	7 / 2.1	6 / 1.2	7.1
28	7 / 2.8	8 / .8	8 / 2.4	6 / 1.2	7.2
29	8 / 3.2	2 / .2	7 / 2.1	8 / 1.6	7.1
30	7 / 2.8	10 / 1.0	8 / 2.4	4 / .8	7.0
31	6 / 2.4	9 / .9	7 / 2.1	4 / .8	6.2
32	6 / 2.4	9 / .9	8 / 2.4	5 / 1.0	6.7
33	8 / 3.2	6 / .6	6 / 1.8	7 / 1.4	7.6
34	9 / 3.6	3 / .3	7 / 2.1	7 / 1.4	7.4

## Ranking Scale for the Above Four Criteria:

1. Conservation Potential: 0 = low potential; 10 = high potential.
2. Institutional Impacts: 0 = great implementation and institutional difficulties; 10 = few difficulties and problems.
3. Socioeconomic Impacts: 0 = undesirable outcome or impacts; 10 = desirable impacts.
4. Environmental Impacts: 0 = undesirable consequences; 10 = desirable consequences.

As the four column headings in Table F.4-5 indicate, the following broad criteria were established as a basis for holistically ranking each of the 34 conservation actions: (a) conservation potential, (b) institutional impact, (c) socioeconomic impacts, and (d) environmental impacts. These criteria agree with the titles of the assessment matrices discussed earlier; Tables F.4-1, F.4-2, F.4-3 and F.4-4, respectively.

### Definitions of Impacts and Requirements

#### Reference Table F.4-1

Time to implement -- Estimate of the time period in which implementation could reach 25 percent of its potential. Time periods NEAR (N) = present to 1985; MID (M) = 1985-2000; LONG TERM (L) = beyond 2000.

Petroleum Energy Reduction Potential -- Estimate of the annual energy conservation potential of the action in quads. If no quantitative estimate is available then a qualitative assessment is used: S = small; M = medium; L = large.

Implementation Cost -- Capital costs to implement the action. If dollar estimates not available, use S = small; M = medium; L = large.

Implementation Manpower -- Human resources needed for implementation of the actions. If qualitative data is not available, use S = small, M = medium, L = large to indicate the degree of this requirement. Specific comment as to major impact is appropriate.

#### Reference Table F.4-2

New Legislation Required -- Is new legislative action at the local, state or national level required for implementation -- yes or no? Comment where appropriate.

Who is to Administer the Action and its Implementation -- Will the actions be administered by private (P), local (L), state (S) or federal government (F) agencies and institutions. Brief specific comment is appropriate.

Organizational Changes Required -- Will organizational change be small (S), medium (M) or large (L)?

Who has a Stake in the Actions and Administration -- Small number of groups or institutions impacted (S), medium number impacted (M), large number impacted (L).

Public Reaction -- If public reaction is expected to be favorable so as to enhance the action use (+), if negative (-), no effect (0). Reaction is considered to be a long run reaction after implementation.

Enforcement -- Indicate those actions which will need some level of enforcement with yes (Y); those which are self-enforcing or not in need of enforcement, no (N).

## Reference Table F.4-3

Travel Time -- Will the action increase (-), have no effect, (0), or decrease (+) travel time?

Safety -- What are the safety and health consequences of the action -- improve (+), no impact (0), decrease (-). Comments where appropriate.

Lifestyle Changes -- How does the action affect lifestyle or accepted patterns of life; no effect (NE), small effect (SE), large effect (LE). Comment where appropriate.

Social Equity -- Does the action impact differently on different groups; minimal differential impact (Mi), moderate differential impact (Mo), large differential impact (L). Comment where appropriate.

Economic Dislocations -- Does the action have no effect (NE), small (SE) or large effect (LE) on patterns of work organization, tax base, sales, unemployment, etc.?

Development Opportunities -- Does the action possess potential for entrepreneurial developments, new programs or projects; no effect (NE), small effect (SE), large effect (LE).

## Reference Table F.4-4

Air Pollution -- Does the action increase (-), have no effect (0) or decrease (+) air pollution?

Noise Pollution -- increase in pollution (-), no effect (0), decrease (+).

Congestion -- Does the action increase (-), have no effect (0), or decrease (+) congestion?

Land Use Patterns -- How does the action effect land use patterns? no effect (NE), small effect (SE), large effect (LE).

Each of the actions were evaluated for each of the four criteria in terms of a ranking scale from 0 to 10 given at the bottom of Table F.4-5. Assignment of rank scores was accomplished as follows. The maximum ranking points of 10 for each criteria were distributed across all the individual impact column headings in Tables F.4-2 through F.4-5. These point assignments were arrived at as a group judgment and are as follows:

Table F.4-1

Time to Implement -- this factor was not included in the ranking process. It was used at a later stage to separate and explore sets of actions in groupings of near, mid and long range implementation time frames.

Energy Reduction Potential -- a score of 4 was assigned if the potential was large; a score of 1 if potential was small.

Implementation Requirements -- each category, cost, manpower and materials were assigned scores of 2 if these requirements were small; 0 if large.

#### Table F.4-2

New Legislation Required -- yes received a 0; no a 1.

Who is to Administer Action -- a score of 2 was assigned if few levels were involved; a score of 0 if many were involved.

Organizational Changes Required -- a score of 2 if changes would be small; 0 if large.

Who has a Stake in the Action -- a score of 2 was assigned if small number of groups impacted; 0 if a large number.

Public Reaction -- this was interpreted as the long term reaction, a score of 2 for good reaction and 0 for poor.

Enforcement -- a score of 0 if enforcement required; 1 if not.

#### Table F.4-3

Travel Time -- 1 if the action reduced travel time; 0 if not.

Safety -- 2 if action increased safety; 0 if not.

Lifestyle Changes -- 2 for no effect; 0 for large effect.

Social Equity -- 2 if the action did not discriminate unequally; 0 if there were gross inequities.

Economic Dislocations -- 2 if few; 0 if many.

Development Opportunities -- 1 if positive; 0 if not.

#### Table F.4-4

Air pollution -- 3 if the action had a strong favorable impact; 0 if none.

Noise pollution -- 2 if good impact; 0 if not.

Traffic Congestion -- 3 if good effect; 0 if none.

Land Use Patterns -- 2 if no change; 0 if major change.

Using the rankings for individual impacts presented above, the transportation task force group (working as a group) assigned consensus ranks for each action. These scores were totaled and appear in the upper left hand area of the boxes in Table F.4-5.

Based on the task group's understanding of the importance of each of the four criteria in Table F.4-5, weighting factors were chosen as shown in the row labeled "Weighting Factor". Conservation potential and socioeconomic impacts were felt to be more important than institutional and environmental impacts and thus received higher weights. Other values could have been chosen which would have yielded a different set of final actions. A sensitivity analysis of the weighting factor could be run if desired.

Rank scores for each action were multiplied by the weighting factors to yield the weighted rankings (lower right of each diagonal). Weighted ranks were summed for each action yielding total weighted scores.

Using the "total weighted score" column in Table F.4-5, it is possible to sift out all actions which rank below some selected cut-off score. Additionally, using the time period estimate from Table F.4-1, it is possible to sift by implementation period.

### Cross Evaluation

It is important to note that not all of the actions previously assessed and ranked can be treated as mutually independent measures.

Some of them, if jointly pursued, might be counter productive. For example, if public-policy were to encourage car pooling and at the same time encourage flexible starting and stopping work times in work places, the two actions tend to conflict with each other and ideally should not both be included in the same package of conservation recommendations.

In an attempt to grapple with this problem, borrowing from [Coates-74], [Krzyczkowski-75], and [Voorhees-74], a cross evaluation matrix was set up and is presented as Table F.4-6. This table and its notes need little explanation. The cross evaluation matrix was accomplished by the task group as a group -- discussing each pair until a consensus classification could be agreed upon.

This cross evaluation matrix then constitutes the third and final stage of a method for identifying a set of consistent energy conservation actions.



## F.5 SOME VIEWS TO THE FUTURE

### Transportation -- Communication Trade-offs

The basic structures of human societies are intimately related to the technology of travel and communication. Indeed [Van Vleck-74] suggests that society has been defined as "an enduring and cooperating social group whose members have developed organized patterns of relationships through interaction with one another." In the development from primitive to modern complex societies of today, transportation and communication technology are simply the technological extensions of locomotion and speech which, in part, have been instrumental in the societal developmental process.

Since transportation and communication are such intimately related to, and basic extensions of, human functions, it is unfortunate that in some ways we are not yet adequately treating them as synergistic systems. Several authors point out that in urban planning, for example, transportation is a major planning factor, but telecommunications seldom enters the planning picture. [Harkness-72], [Reid-71].

Consideration of the substitution of travel by computer-telecommunications has long been of interest to a spectrum of persons ranging from the science fiction writer to the rehabilitation specialist interested in creating information handling jobs for home-bound persons [Overby-74-1]. With growing environmental concern with automobile pollution, the recent OPEC perturbation in our energy supply, etc., there is an increasing amount of literature looking at energy conservation, socioeconomic, and environmental consequences of substitution of travel with telecommunications.

It is the purpose of this section to briefly call the readers' attention to some of the literature, to point out a few gross orders of magnitude, to point out energy conservation potentials, and to ask a few questions as to what needs to be done in the future relative to the energy conservation potential in telecommunication substitutes for travel.

Many authors indicate that improved telecommunications capability, rather than causing a reduction in travel demand, might very well produce a synergistic increase in the propensity to travel; thus, suggesting that it is folly to explore here for energy conservation. Historically, such arguments can be supported with data; however, as socioeconomic environmental pressures mount and as fuel costs and governmentally produced travel disincentives increase, we may well see trade-offs in favor of various forms of computer-telecommunications modes.

Various facets of the transportation communication trade-off including energy conservation potential can be found in [Day-74], [Dickson-73], [Harkness-72], [Krzyczkowski-74], [Lathey-75], [Overby-74-2], and [Tyler-74].

Illustrative of some of the energy conservation potential discussed in the above is the following:

Travel for one person between Glasgow and London, England by air would require approximately 5 times as much direct energy expenditure as would a three-hour video conference between London and Glasgow -- a conference in which more than two persons could participate. If a "sound only" system were used, the airplane trip consumes roughly 600 times as much energy as a three-hour phone conference.

For the amount of energy consumed in gasoline to drive 30 miles round trip to work, it would be possible for two persons to remain in two way local area video phone contact for 125 hours.

Use of the telephone vs. the automobile for information acquisition, exchanges, etc. could result in a dollar cost ratio of 1:26 and an energy consumption ratio of 1:500 in favor of the telephone.

The above direct energy cost examples are sometimes criticized because they include only the direct energy used to operate the automobile or telephone, etc. It is suggested that a better measure would be to include all the indirect energy costs in the comparisons. [Massey-75] makes calculations of the indirect energy cost of producing transportation vehicles and the energy costs in building the highways, railways and airport runways. He concludes that these indirect energy costs represent but a small fraction of the direct energy consumed in vehicle operation. Since the direct energy costs of telephones and even video phones are so low compared to automobiles, it is conceivable that indirect energy costs (build, install and maintain a communication system) could be a higher portion of total costs and thus cause the communication system to lose a small amount in relative advantage to the automobile. A good set of calculations of indirect energy costs for communication systems needs to be performed. An even more interesting comparison between communication and transportation systems would be one which takes into consideration total resource utilization. How do the materials and manpower as well as energy requirements compare for communications vs. transportation? An estimate would place the balance, at least on energy and materials, in favor of communication systems. Some answers to questions like these might be obtained through econometric and input-output modeling like that being carried out at the University of Illinois Center for Advanced Computation [Hannon-75]. A preliminary exploration of the transportation-communication trade-off, using input-output techniques has been carried out and is discussed in Chapter 8 of ECSTAR.



With energy and cost savings as indicated above, why do we not have a landslide rush to substitute telecommunications for travel? The answers are not simple ones. Large shifts from transportation to communications would require major lifestyle and institutional changes and could meet with considerable resistance. Small and gradual shifts, however, are already taking place as our society moves from a blue collar to a white collar (information handling) society. It behooves us, therefore, to study and assess these shifts. It may also be necessary to consider governmental policy which could create a milieu of incentives to encourage shifts from travel to communications. For example, what modification of the tax laws might be made so as to encourage such shifts? What would be the consequences and impacts of this public policy?

The National Science Foundation is presently supporting a number of large research and demonstration projects relating to telecommunication applications. Stanford Research Institute recently received a substantial grant for study, including the energy conservation potential in substituting telecommunication for travel [Hough-75].

Suggestions for future study in this area are contained in most of the previously cited materials. There appears to exist considerable potential for long range transfer of NASA technology in the trade-off between travel and communication. NASA, in its space operations, has developed a massive communications system competence -- hardware, software and organizational arrangements. It has great experience in remote operations using sophisticated teleoperator, man-machine, and man-man communications technology [NASA-69]. These broad areas of NASA competency placed in juxtaposition to present and future computer-telecommunications possibilities [Overby-74-2] are suggestive of important technology transfers of NASA knowhow. Perhaps NASA should actively explore from both a "market pull" and "technology push" point of view the transfer and diffusion of its technological capability in this area. For example, what are some of the developing information needs in our society and the technological requirements to meet these needs? How might NASA competence be addressed in response to these needs? As pointed out earlier, we are inexorably becoming a nation of information processors as contrasted to blue collar material handlers. Information processing is suggestive of travel substitution through communications technology resulting in new patterns of work organization. Implicit in these changes are energy saving possibilities as discussed above. Can NASA technology transfer and diffusion be applied in this area? It seems that some effort ought to be expended in exploration of these possibilities.

### Fixed Rail Transportation

The urban mass transit systems of the future are foreseen as operating on fixed rails, electrically powered and highly automated. They will doubtless contain many special features to increase safety and speed of serving passengers. Special systems will probably be installed to transport passengers from large parking lots to rail transit stations.

It may prove economically feasible to electrify say around ten percent of the nation's 220,000 miles of railroad. This will cost around \$2 billion (an enormous sum until we look at the \$50 billion spent on the interstate highway system -- a cross country network of modern highway where traffic can move legally at the tremendous speed of 55 mph!). Furthermore, if this railroad electrification should be done, it still leaves 198,000 route miles to be powered by other means. In a nuclear electric economy (which looks like it may be our destined future for some time), some kind of synthetic fuel(s) are needed for applications where electrification is either impossible or unfeasible. In this regard, hydrogen, metallic hydrides, methanol, ethanol and ammonia are all candidate fuels, but there are several more.

It appears that there will be a need for cooperative contracts with the various electric utilities in the regions common to the railway systems that become electrified. Furthermore, a tremendous amount of capital must be raised since the original electrification cost runs on the order of \$100,000 per track mile. There are several methods of accomplishing this financing if further study shows it to be advisable. The federal government will be interested and, without doubt, will follow the action with much interest. One factor on the bright side regarding this huge financial problem is that annual operating savings would be large enough to recover the original investment in less than five years.

Total installation time per 1000 mile module is estimated at about three years. The annual energy required for operation is projected at around a billion kWh.

Future locomotives may use hybrid systems. For instance, they may use regenerative systems whereby the energy from braking is not dissipated as wasted heat but rather stored in some device (e.g., a maraging steel flywheel). If otherwise wasted energy is stored in this fashion, it will not only conserve energy, but will enable the use of a much smaller engine and hence lower peak demand -- a most vital factor concerning electric utility rates.

Railroads would do well to consider owning and operating trucks and material handling equipment (perhaps electric) at each freight terminal. In this fashion they could move goods to and from the customers' doors and thus capture more of the freight business now handled by trucking firms. The railroads would enjoy a specific advantage in this regard by using electric delivery vehicles when fuel prices become unreasonably high.

The railroads may benefit in the passenger business by promoting the auto train. In this manner the passengers can enjoy the trip, busy executives can continue with their office work enroute, nobody suffers from driving fatigue, the travel is much safer, energy is conserved, travel continues 24 hours per day while passengers sleep and finally the traveler

still has his car with him at his destination (a factor which has caused him to drive heretofore and caused the railroads to lose nearly all of their passenger business). Once again, railroads should gain on this point in an electrical economy because electric autos, while excellent for urban and interurban driving, will not be practical for cross country travel. Going on a long trip on the auto train would be similar to taking one's car with him to Europe.

Railroads may also explore the merits of providing reasonably priced auto rentals at each terminal for those passengers who do not own or take their cars. Again, this would help to overcome the cause for losing passenger business in the past.

### Vehicular transportation

Carpools and vanpools will doubtless be encouraged much more in the future. Incentives will probably grow. Citizen action groups, the government and employers will doubtless be involved. Bus and carpool lanes for crowded city streets will be common. Large parking lots will be provided with some type of people moving system to transport large numbers of people rapidly to mass transit terminals or central business districts. Special systems will also be provided for safe, rapid and efficient movement of products, materials, and goods into and out of central business districts.

The battery powered electric vehicle may become common in urban and suburban areas especially for stop and go delivery service. As a matter of fact, the current required cost of necessary pollution control devices, the increased fuel cost and much higher service and maintenance costs of multistop gasoline fueled fleet delivery vehicles, should cause fleet operators to seriously examine the attributes of currently available electric vehicles. In this regard, the Postal Service is adding 350 electric-powered Jeeps to its delivery fleet this year. Currently there are three electric passenger vehicles available in the United States. The prices vary from \$2,690 to \$5,000. Also there are three electric delivery vehicles available. At present, the electric vehicle business is growing. Some people are predicting that there will be around 5 million electric cars in service by 1985.

From a noise and air pollution standpoint, electric vehicles are ideal for urban and suburban use. The only requirement is sufficient electrical energy for charging the batteries. This can be done at night which will help electric utilities by utilizing some of their excess night capacity. If a nuclear electric economy prevails in the future, there should be no shortage of electrical energy for charging batteries.

Half a dozen different types of storage battery are receiving current attention. The Lithium-Sulfur battery developed at the Argonne National Laboratory looks particularly interesting. These batteries have produced five times as much energy as comparable lead-acid batteries. They are estimated to have lives of 5 to 8 years and be capable of sustaining between 1000 and 1500 charge and discharge cycles. A recent design study [Walters-75] has shown that a 150-V battery with a storage capacity of 42 kWh can be

used to power a 1975 Ford Mustang II. It is 36" long, 21" wide by 22" high and weighs 800 pounds. In stop and start city driving, the range of the car will be approximately 120 miles. It can accelerate to 50 mph in 15 seconds and to 60 mph in 23 seconds. The maximum speed will be about 80 mph. Projected cost will vary from \$800 to \$1,250 whereas an equivalent lead-acid storage battery will cost around \$2,500.

The battery of an electric vehicle must be charged daily and this is a slow process. It is visualized that parking lots in cities and at railroad stations and airports could be equipped with electrical outlets where motorists could have their batteries recharged while parking. In this way, the parking fee would apply partly for the electrical energy.

The battery powered vehicle does not idle while stopped as in the case of a gasoline powered vehicle. It does not cause noise or air pollution and neither does it burn petroleum. It has a much higher operating efficiency than a gasoline fueled vehicle in addition to having much lower maintenance costs. It is ideal for urban and interurban use.

It is not suited for extended highway travel because of the refueling time required but seems ideal for use with the auto train. It seems that this application would prove beneficial to both the motorist and the railroads. Railroads and airports might also seriously consider the operation of electric car rental services.

### Alternate Fuels

Alternate fuels will play a vital role in the future even in a nuclear-electric economy. Liquid hydrogen exhibits a great potential as an aviation fuel.— Given a source of energy, hydrogen can be extracted in essentially unlimited amount. It is worth noting that hydrogen can be produced by electrolysis or water splitting methods. Its use as a fuel greatly improves the performance of subsonic and supersonic aircraft, whereas for hypersonic aircraft, its use will be mandatory. Liquid hydrogen is no more hazardous than methane or gasoline [Small-74] and furthermore it possesses several safety advantages. The improved performance of hydrogen engines more than compensates for the increased size and added weight of the necessary cryogenic fuel tanks. Use of hydrogen in a subsonic aircraft permits a change in fuel tankage arrangement which yields a drastic reduction in takeoff weight. [Small-74] Air pollution is vastly reduced; burning hydrogen eliminates carbon-related products simply because there is no carbon. The noise level is reduced when burning hydrogen as the fuel. The cost will certainly come down as use increases. It looks as though hydrogen could possibly become the ground

transportation fuel of the future, depending on many factors. A few are portrayed in Tables F.5-1 [Gregory-73] and F.5-2 [Malliaris-73]. In Table F.5-2, decimal numbers have been normalized with respect to gasoline. The "weight" and "bulk" columns are based upon an equivalent 18 gallons of gasoline. The fire hazard column is rated as Poor, Fair, Good, and Excellent. Toxicity appears in the next column and is rated as follows: (0: no harm), (1: slight but reversible harm), (2: moderate harm; could be irreversible), and (3: severe; could be fatal). Wherever two numbers appear, the first refers to inhalation and the second to ingestion. The remaining columns use the same rating symbols as used for "Fire Hazard".

In view of the results of a preliminary assessment, [Malliaris-73], the first choice for automotive fuel is to derive synthetic gasoline from shale, coal, or by any other means, provided that it is economically competitive with gasoline. Secondly, ethanol should be considered as an alternate fuel, if it can be made economically competitive. Propane, methanol, and liquid methane, in that order, are next in the ranking. Cryogenic hydrogen, hydrogen/oxygen, and magnesium hydride appear relatively unattractive. The metal hydrides need further research and development. Ammonia and hydrazine are even less attractive -- their poor toxicity rating presents a serious problem.

An available technology exists today for utilizing solar energy to grow suitable crops and then convert them into ethanol by fermentation. In this fashion, large scale solar-energy farms could be utilized to produce vast quantities of ethanol, but the economics have not yet been assessed.

Methanol can be synthesized in vast quantities from water-derived hydrogen and coal-derived carbon dioxide. It is cleaner burning than gasoline and is, therefore, more ecologically acceptable. In spite of the unfavorable energy density, the fuel economy of methanol is as good as that of gasoline. A methanol fueled engine is difficult to crank at low temperature. Also, deterioration of some types of metal plating, certain plastics and a few die cast carburetor parts have been reported. It is believed, however, that these problems can be overcome.

Ammonia will not yield any carbon compounds as do atmospheric pollutants and furthermore, its nitric oxide emission will be less than one-fifth of that produced from gasoline. It has an extremely high octane rating and achieves it without the use of lead or other additives. Ammonia, although toxic, has a characteristic odor and, furthermore, it is lighter than air so that it has a tendency to rise in the atmosphere and disperse. It is readily vaporized which is very essential for spark ignition engines. It is noted, however, that copper, brass, and zinc are attacked by it and hence any affected parts normally constructed of these materials should be made of steel or aluminum.

TABLE F.5-1 .COMPARISON OF STORAGE PROPERTIES OF VARIOUS FUELS [GREGORY-73]

Fuel Grade	SI (Metric) Units						Conventional Engineering Units					
	Energy Density			Amount Equivalent to 20 gal Gasoline			Energy Density			Amount Equivalent to 20 gal Gasoline		
	Density kg/m <sup>3</sup>	J/kg × 10 <sup>3</sup>	J/m <sup>3</sup> × 10 <sup>5</sup>	l	kg (fuel)	kg (tank and fuel)	Density, lb/ft <sup>3</sup> (60°F)	Btu/lb	Btu/ft <sup>3</sup>	gal	lb (fuel)	lb (tank and fuel)
Typical gasoline	702	44,380	311,700	75.7	53.1	68	43.8	19,080	835,700	20.0	117	150
Methane gas (CH <sub>4</sub> – 1.38 × 10 <sup>7</sup> N/m <sup>2</sup> , 2000 psia)	114	50,000	56,850	415	47.2	500	7.09	21,500	152,400	110	104	1100
Liquid propane (LPG – 6.89 × 10 <sup>5</sup> N/m <sup>2</sup> , 100 psia)	510	44,400	236,000	100	51.1	85	31.8	19,900	632,800	26.4	112	180
Methanol (anhyd CH <sub>3</sub> OH)	797	20,100	160,200	147	117	141	49.7	8,640	429,400	38.9	253	310
Ethanol (anhyd C <sub>2</sub> H <sub>5</sub> OH)	795	26,860	213,700	110	88.0	107	49.6	11,550	572,900	29.2	194	235
Liquid hydrogen (at NBP)	71	120,900	85,900	275	19.5	136	4.43	51,980	230,300	72.6	43.0	300
Hydrogen gas (1.38 × 10 <sup>7</sup> N/m <sup>2</sup> , 2000 psia)	1.07	120,900	12,920	1820	19.5	2090	0.667	51,980	34,550	482	43.0	4600
Metal hydride (Mg <sub>2</sub> Ni H <sub>x</sub> )	1760	10,100	179,000	132	233	284	110	4,350	479,900	34.8	513	625
Liquid ammonia (at NBP)	771	18,600	143,500	164	127	152	48.1	8,000	384,800	43.3	279	335

ORIGINAL PAGE IS  
OF POOR QUALITY

TABLE F.5-2 [MALLIARIS-73] RELATIVE PROPERTIES OF CERTAIN NOVEL FUELS FOR REFERENCE PURPOSES

	Relative Gallons per BTU	Relative Pounds per BTU	Weight (lbs)	Bulk (cu. ft.)	Fire Hazard Rating	Toxicity	Combustion Rating	Distrib. Logistics	Tankage Cost
Gasoline	1.0	1.0	125	3	F	1-2	G	E	E
Methane (Liq.)	1.6	0.9	210	5	F	0-1	E	F	F
Propane	1.1	1.0	185	4	F	0-1	E	F	G
Methanol	1.8	2.1	250	6	G	1-3	G	F	G
Ethanol	1.4	1.6	180	3	G	1-2	G	G	E
Liq. Hydrogen	3.9	0.4	150	13	P	0	G	P	P
Liq. Hydr/ Liq. Oxyg.	5.7	3.6	550	18	P	0	E	P	P
Magnesium Hydride	4.1	4.9	700	14	P	0	E	P	P
Ammonia	2.0	2.3	300	7	G	3	P	P	F
Hydrazine	1.6	2.3	265	5	E	3	P	P	F

There are other factors which may overshadow those tabulated in this section, such as availability of needed raw material, economics of production, distribution and consumption, and finally the energy intensity of synthesis. These factors may not only cause a change in indicated ranking, but, when coupled with new developments, could cause an entirely new and different fuel to emerge as the transportation fuel of the future. It will be interesting indeed to watch for the fuels of the future.

The following references were used in writing this section:

[Ankrum-74]  
[Bader-75]  
[Dietz-75]  
[Fisher-74]  
[Fleming-75]  
[Gregory-73]  
[Hafer-75]  
[Heck-75]  
[Hodson-74]  
[Holt-75]  
[Ingamells-75]  
[Kucera-75]  
[Lancaster-75]  
[Mulliaris-73]  
[Morris-75]  
[Powell-75]  
[Schaefer-75]  
[Shuldiner-75]  
[Silien-75]  
[Stewart-74]  
[Tillman-75]  
[Vanderslice-74]  
[Walters-75]  
[Weiner-75]  
[Whalen-75]  
[Wyman-69]

## F.6 ENERGY ENVELOPE CURVES FOR THE TRANSPORTATION SECTOR

In an effort to clarify the potential savings of energy by various actions, energy envelope curves were produced for the movement of passengers and freight. In each case, the projected passenger-miles and ton-miles were assumed to be unchanged from the historical growth pattern. [Ford-74, 444-454]

### F.6.1 PASSENGER TRAFFIC

The United States population growth was assumed to be that shown by the U. S. Census Bureau. [Census-72] The historical growth, HG, of our population, and the total number of passenger-miles are shown in Table F.6.1-1.

Several of the assumptions and other required data to produce these energy envelopes were taken from the report "A Time to Choose, America's Energy Future", which was funded by the Ford Foundation. [Ford-74, 440-441] These assumptions included:

"The heating value of gasoline is 125,000 BTU's per gallon.

Cars are driven, on the average, 10,000 miles per year. This is an average figure for 1970 and has changed a little over the years.

The urban load factor is 1.4 passenger-miles per vehicle miles; the rural value is 2.4 pm/vm. [DOT-1972]

The average rural fuel economy (FE)<sub>r</sub> is assumed to be 1.3 time the urban fuel economy (FE)<sub>u</sub>. Both are related to the average fuel economy (FE)<sub>av</sub> by

$$\begin{aligned} (FE)_r &= (1 + 0.3 f_u) (FE)_{av} \\ (FE)_u &= \frac{(1 + 0.3 f_u) (FE)_{av}}{1.3} \end{aligned} \quad (F.6.1-1)$$

where  $f_u$  is the fraction of  $v_m$  driven in urban areas."

In order to generate a curve representing the maximum amount of energy required to provide the passenger-miles shown in Table F.6.1-1, the following assumptions were made. First, since the U. S. is extensively laced with roads and since the automobile is more energy intensive than either the bus or the railroad, it was assumed that all passenger traffic was shifted to automobile. However,



TABLE F.6.1-1  
HISTORICAL GROWTH OF THE U.S. POPULATION AND  
THE NUMBER OF PASSENGER-MILES TRAVELED

YEAR	POPULATION	PASSENGER-MILES
1970	205 million	$1.90 \times 10^{12}$
1975	215	$2.16 \times 10^{12}$
1985	236	$2.50 \times 10^{12}$
2000	265	$3.71 \times 10^{12}$

TABLE F.6.1-2 PASSENGER TRANSPORTATION  
REQUIREMENT (quadrillion BTU's)

H G				MAXIMUM ENERGY REQUIRED				
	1970	1975	1985	2000	1970	1975	1985	2000
Auto	8.2	10.0	12.5	15.2	8.75	10.67	13.25	16.12
Bus	0.2	0.2	0.2	0.2	-	-	-	-
Air	0.9	1.32	2.76	6.20	0.90	1.32	2.76	6.20
Rail	0.03	0.04	0.05	0.09	-	-	-	-
	9.3	11.6	15.5	21.7	9.7	12.7	16.0	22.3

TABLE F.6.1-3 MINIMAL PASSENGER TRANSPORTATION  
REQUIREMENT (quadrillion BTU's)

	MODAL SHIFTS				IMPROVED EFFICIENCY			
	1970	1975	1985	2000	1970	1975	1985	2000
Auto	2.82	3.40	4.09	4.95	2.82	3.40	2.71	2.21
Bus	1.81	2.05	2.47	2.91	1.81	2.05	2.22	2.18
Air	0.56	0.82	1.72	3.87	0.56	0.82	1.55	2.91
Rail	<u>0.94</u>	<u>1.10</u>	<u>1.40</u>	<u>2.13</u>	<u>0.94</u>	<u>1.10</u>	<u>1.28</u>	<u>1.60</u>
	6.1	7.4	9.7	13.9	6.1	7.4	7.8	8.9

because aircraft are more energy intensive than automobiles, the projected historical growth pattern for air passenger travel was retained. Table F.6.1-2 shows both the historical growth pattern and the maximum amount of energy required taking into account the shifts of mode assumed.

Next, an estimate of the lowest amount of energy required to achieve the same amount of passenger travel was produced. These calculations were made in two parts; first, by assuming substantial shifts in the mode of transportation, and secondly, by assuming increases in the efficiency of each mode. These assumptions are listed as follows:

Extensive urban carpooling was assumed with an average of 3 passenger per vehicle for 50% of all urban miles.

The remaining 50% of urban miles were assumed to be provided by buses.

A shift of 50% of intercity, or rural, passenger-miles to bus and rail was assumed. One-half of this amount was carried by each mode.

Next, domestic airline travel was assumed to be cut by one-half and shifted to rail. The remainder was assumed to be carried by the airlines, and no change in international traffic was assumed.

Finally, fuel efficiency improvements for each mode were assumed. These improvements were assumed to occur linearly with time. A 100% improvement in fuel efficiency, by the year 2000, was assumed for the automobile. On the other hand, only a 25% improvement, by the year 2000, was assumed for the other modes. These changes were assumed to begin in the year 1975.

Using these assumptions, 1-4, energy requirements based on modal shifts were evaluated, then the effects of efficiency improvements were included. Both modifications are shown in Table F.6.1-3. A plot of these results is shown in Fig. F.6.1-1.

#### F.6.2. FREIGHT TRAFFIC

In similar manner, the envelope curves for movement of freight were established. To determine the maximum energy envelope, it was assumed that all energy carried by the rails was shifted to

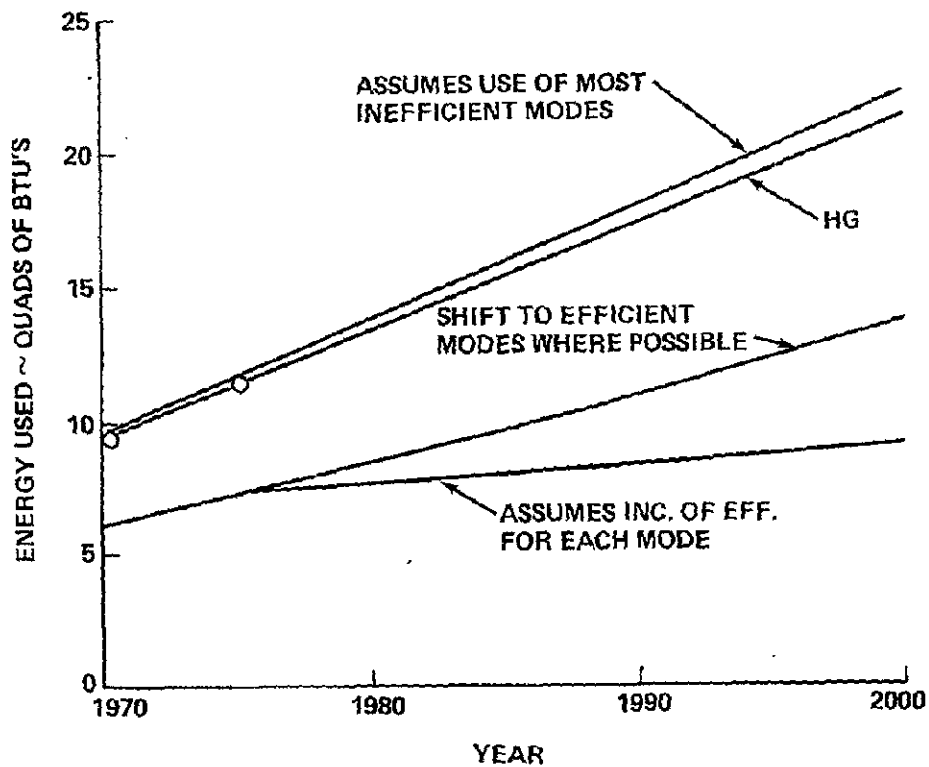


FIGURE F.6.1-1. ENVELOPE OF PROJECTED ENERGY REQUIREMENTS FOR PASSENGER TRAVEL

trucks. The average fuel efficiency for all trucks was taken to be 5,750 BTU/ton-mile while for trains the fuel efficiency was taken as 670 BTU/ton-mile. [Ford-74] Air freight was assumed to be the same as the historical growth pattern. Energy use patterns are shown in Table F.6.2-1. It should be emphasized that the number of ton-miles is the same for both cases. To include all transportation energy required, operation of farm machinery and miscellaneous uses were included in the freight category. Miscellaneous includes ship requirements.

To establish the minimum energy requirements, several assumptions were made.

The energy requirements for farm machinery were assumed to be the same.

The energy requirements for the miscellaneous category were assumed to be the same.

According to [Ford-74 pg 451], "40% of all freight tonnage in 1967 could have been hauled by either truck, or rail. However, trucks carried over 80% of this cargo. These estimates along with the actual ton-miles carried by both rail and truck were used to establish that trucks were necessary for about  $174 \times 10^9$  ton-miles of cargo; this is about 14% of the total. This percentage has been assumed constant in the required calculation, i.e., the other 86% was assumed to be carried by rail.

Also, all-domestic air freight was assumed to be moved by rail and truck, and in the same percentages as stated previously.

Finally, air, truck and rail modes of transportation were assumed to improve in efficiency in a linear fashion by 25% by the year 2000.

Both the effects of shifts of mode and improvements in efficiency are shown in Table F.6.2-2. These results are plotted in Fig. F.6.2-1. Adding the energy results produced for freight and passenger transportation yields Figure F.6.2-2. Then, the domestic petroleum supply and the total oil supply have been included in Fig. F.6.2-3, as well as the results of the technical fix and zero energy growth as studied in the Ford Foundation Project.

It is this curve that is rather fascinating. First, it shows the difficulties ahead for the country if the historical growth pattern is allowed to proceed unchecked, and the severe dependence on foreign oil that would result. The Figure also provides a solid argument for either alternative fuel resources, or required large changes in lifestyle, or both.

TABLE F.6.2-1 FREIGHT TRANSPORTATION ENERGY REQUIREMENTS (quadrillion BTU's)

	H G				MAXIMUM ENERGY REQUIRED			
	1970	1975	1985	2000	1970	1975	1985	2000
Air	0.30	0.50	1.60	5.40	0.30	0.58	1.60	5.40
Truck	3.50	4.20	5.30	6.50	7.96	9.52	13.11	20.06
Rail	0.52	0.62	0.91	1.58	-	-	-	-
Farm mach	1.10	1.20	1.30	1.70	1.10	1.20	1.30	1.50
Misc.	0.90	1.00	1.30	1.70	0.90	1.00	1.30	1.70
	<u>6.3</u>	<u>7.6</u>	<u>10.4</u>	<u>16.7</u>	<u>10.3</u>	<u>12.3</u>	<u>17.3</u>	<u>28.7</u>

TABLE F.6.2-2 MINIMUM FREIGHT TRANSPORTATION ENERGY REQUIREMENTS (quadrillion Btu's)

	MODAL SHIFTS				IMPROVED FUEL EFFICIENCY			
	1970	1975	1985	2000	1970	1975	1985	2000
Air	0.10	0.24	0.72	2.49	0.10	0.24	0.54	1.87
Truck	1.00	1.37	1.85	2.89	1.00	1.37	1.39	2.17
Rail	0.81	0.95	1.28	2.01	0.81	0.95	0.96	1.51
Farm Mach.	1.10	1.20	1.30	1.50	1.10	1.20	1.30	1.50
Misc	0.90	1.00	1.30	1.70	0.90	1.00	1.30	1.70
	<u>3.9</u>	<u>4.8</u>	<u>6.5</u>	<u>10.6</u>	<u>3.9</u>	<u>4.8</u>	<u>5.5</u>	<u>8.7</u>

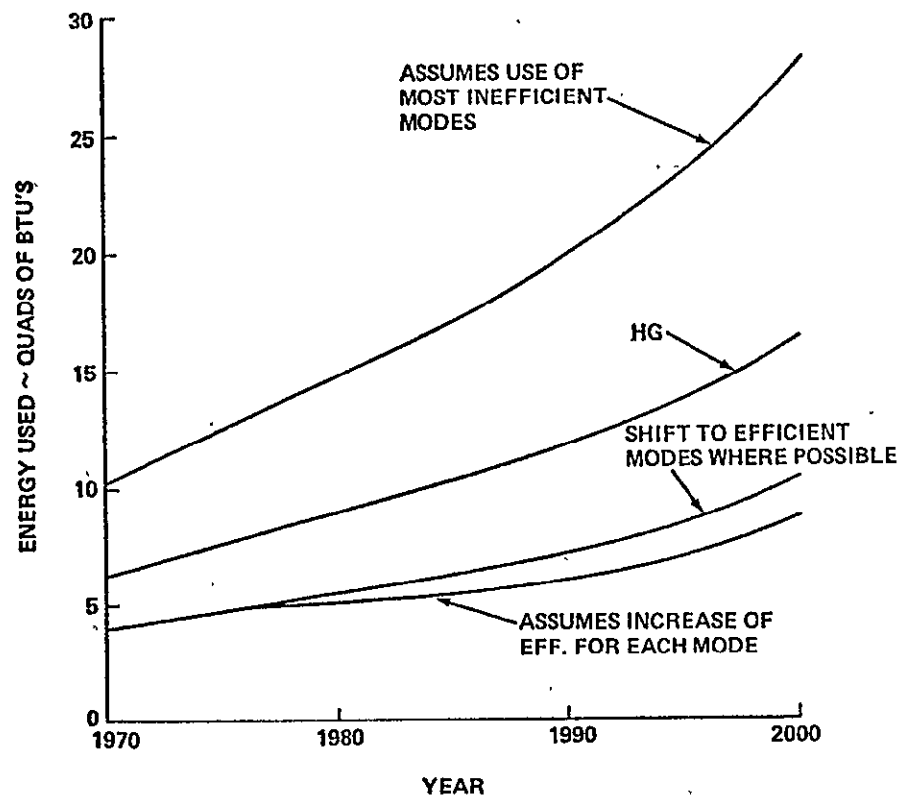


FIGURE F.6.2-1. ENVELOPE OF PROJECTED ENERGY REQUIREMENTS FOR FREIGHT TRANSPORTATION

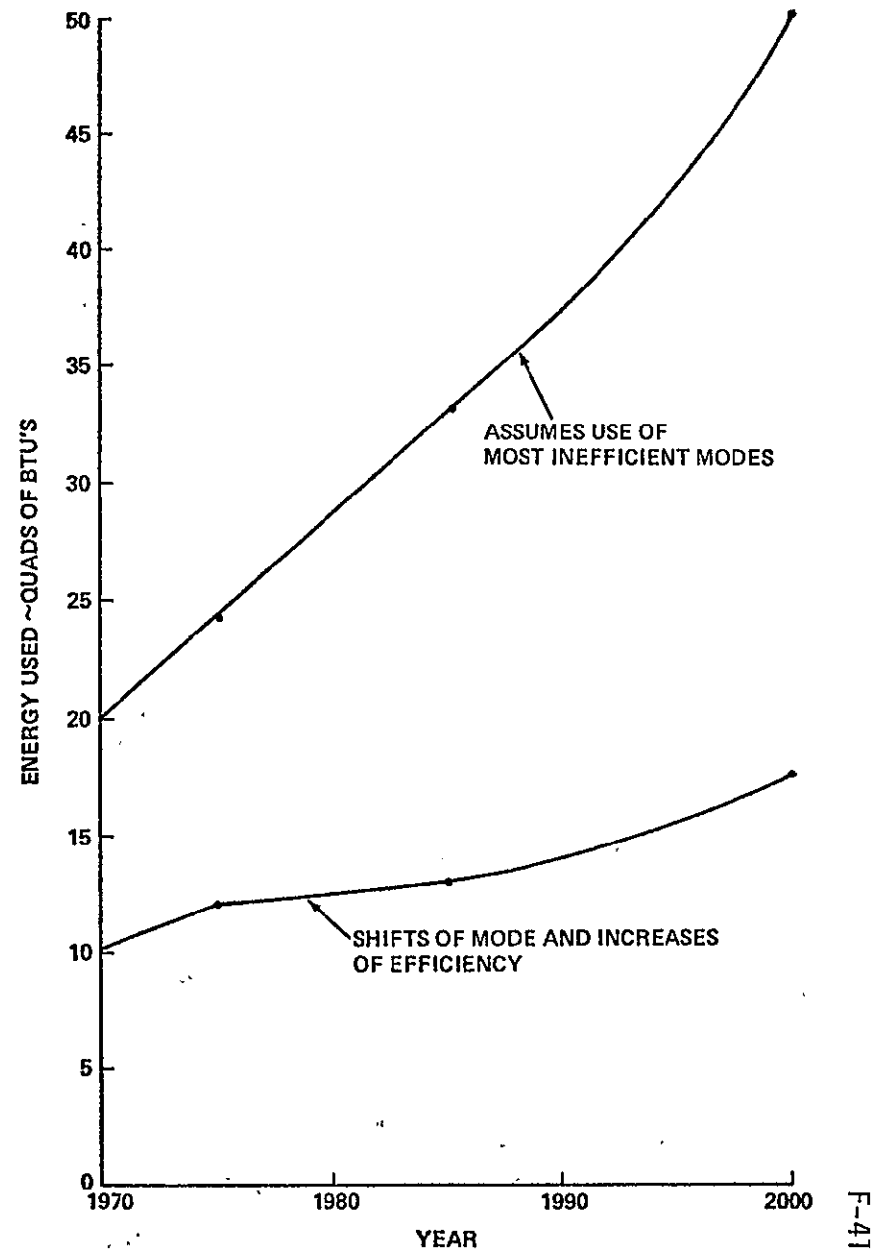


FIGURE F.6.2-2. ENVELOPE OF PROJECTED ENERGY REQUIREMENTS FOR TRANSPORTATION

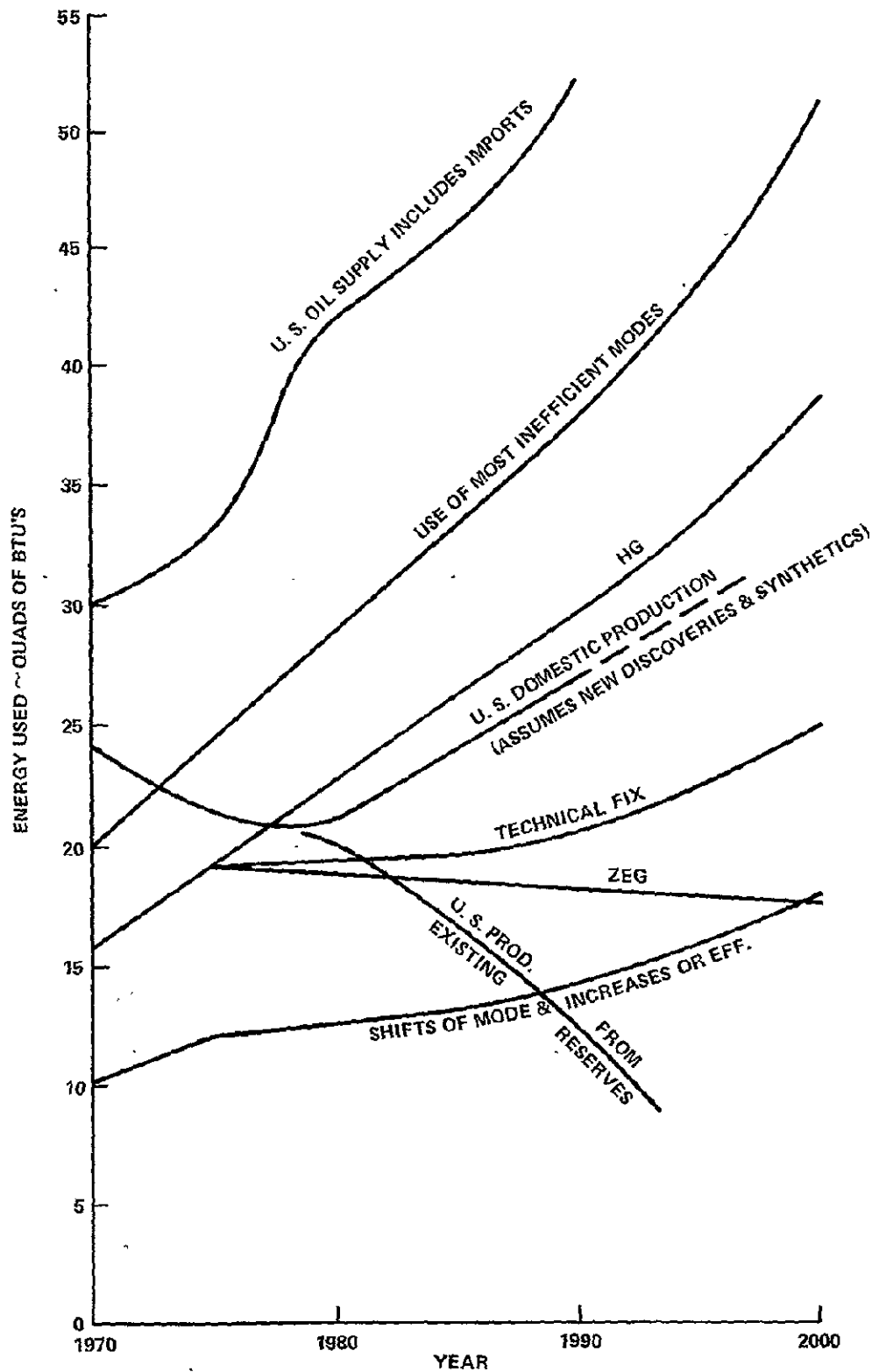


FIGURE F.6.2-3. ENVELOPE OF PROJECTED ENERGY REQUIREMENTS FOR TRANSPORTATION

## - APPENDIX G. CONSERVATION IN THE RESIDENTIAL AND COMMERCIAL SECTOR

### G.1. INTRODUCTION

A detailed analysis of conservation actions relevant to the sector leaves one with the conclusion that the potential for savings is great and, if the nation is determined to curtail its dependence on oil imports, concerted efforts must be made to achieve this potential. The task will not be easy, however, since many of the actions require significant life style changes that are difficult to accomplish. For example, turning back thermostats at night, reducing lighting, and maintaining proper conditioning of appliances are apparently easy tasks to achieve, but evidence indicates otherwise. Even the retrofitting of homes is hindered by initial costs, though the payback period is short. Also, consumption patterns are very unpredictable -- families living in nearly identical homes may vary radically in energy demands.

Furthermore, many of the conservation actions that are cited as "instant" solutions to the energy crisis are those with only mid to long term potential. Solar energy is one example; the heat pump is another.

There are ways, however, of accomplishing very significant savings in the residential/commercial sector. Three approaches are viable -- adjusting price-structure, mandating actions, and educating consumers. Of these three, the first two appear to be the most feasible, but they are not without a price. Higher utility bills adversely affect the poor and the elderly on fixed incomes and leads one to the conclusion that a dramatic rise in the price of gasoline might accomplish the same savings without as much societal disruption. One can carpool to work or drive a smaller automobile. It may be more difficult, however, for the elderly to lower thermostat settings in the winter or do without air conditioning during air pollution episodes. Likewise, strict mandatory measures can be quite distasteful.

But the alternatives, such as voluntary savings accomplished through education processes, have a minimal effect in a nation without a true conservation ethic. In the time period from June, 1973 to June, 1974, gasoline demand increased by 2.9 percent even though prices had jumped by 42 percent and the nation was in the midst of a massive indoctrination program to save energy.



In order to realize the potential afforded the residential/commercial sector for conserving energy, we recommend that the following actions be properly assessed in order to determine their overall feasibility.

Provide tax incentives for a massive retrofitting of homes.

Mandate 50-30-10 footcandle standard for all commercial buildings. The "delamping" program in the General Service Administration is an excellent indication that "policy" actions can succeed with minimum impacts.

Accomplish 500,000 solar installations per year by 1980 by subsidizing industry for their production and providing tax incentives for installation in all new building starts.

Adopt differential pricing of electricity for households.

Investigate the standardization of appliances.

Adopt guideline of 30,000 BTU/sq.-ft. for energy consumption in residential/commercial buildings.

Encourage the building of smaller homes by raising property taxes.

Train "energy consultants" to work with the homeowners and small commercial establishments to accomplish savings and to educate homeowners on concepts such as life-cycle costing.

Encourage greater consumer acceptance of heat pumps and increased market penetration, especially in Southern regions or as an alternative to electric resistance heating.

Increase funding for implementation of technologies developed by NASA and similar agencies. (Ex. a midwestern utility is presently using an aerial survey technique developed with NASA support to measure rooftop heat loss from homes and commercial buildings and show their owners whether they are wasting fuel because of inadequate insulation.)

#### G.1.1. IDENTIFYING AND ASSESSING CONSERVATION ACTIONS IN THE RESIDENTIAL/COMMERCIAL SECTOR

As the group proceeded with the task of identifying individual conservation actions it became obvious immediately that the actions could be classified into a number of categories. At first the most obvious classification seemed to be under the broad topics -- increased efficiency, reduced demand and substitution. The task group actually divided into three sub-task groups

for the specific purpose of considering the actions under these headings. It soon became apparent, however, that actions may not only increase efficiency but also reduce demand. Of course, substitution actions automatically reduce demand of a scarce resource. By retrofitting one reduces the space heating requirement while increasing the overall efficiency of the building. Utilization of solar hot water heating may reduce demand for the scarce resource natural gas.

Another obvious means of classification was by time frame. Near or short term actions are those that are implemented before 1985; mid term actions fall into the time period 1985-2000; and long term actions are those that require major technological developments and will not be implemented before 2000. This classification served a very useful purpose. If an immediate response to the OPEC embargo was one of reducing demand on foreign imports by conservation actions, then it seemed logical to identify those actions that bring immediate relief. Planting shade trees was not one such action for obvious reasons. Neither was solar energy, although it may have tremendous potential in the future.

In addition, most actions may be identified under the general categories of those that: (1) impact HVAC systems (heating, ventilating, and air conditioning), (2) reduce lighting, (3) affect appliances or (4) general housekeeping measures.

Whatever the classification, it was necessary to identify a number of conservation actions and then filter these through an evaluation matrix. The purpose of such a procedure was to eliminate a number of actions by an initial qualitative assessment and in the process identify those with possibly high potential. See Figure G.1.1-1 for a diagram of the overall approach. Section G.1.3 contains a list of conservation actions relevant to the sector. In a proper analysis all of these actions would be assessed qualitatively by utilization of an action evaluation matrix such as that depicted in Table G.1.1-1. The matrix provides for consideration of potential savings, ease of implementation, requirement availability impacts and a final listing as to overall potential. Although time did not allow all actions to be assessed, Table G.1.1-1 lists several assessed actions to illustrate the methodology.

The assessment code allows one to range from a +H to a -H where +H is highly favorable or positive and -H refers to a highly unfavorable action. To illustrate, a +H rating for capital availability indicates a highly favorable response to the criteria "Is the capital available?". Likewise, a -M rating for environmental impact indicates the likelihood of unfavorable environmental disruption if the action is implemented. After a qualitative assessment, several specific actions were individually assessed to determine their overall feasibility by considering major requirements and impacts. Detailed assessments for the selected actions are summarized in Chapter 7 and listed in Appendix G.2 through G.6.

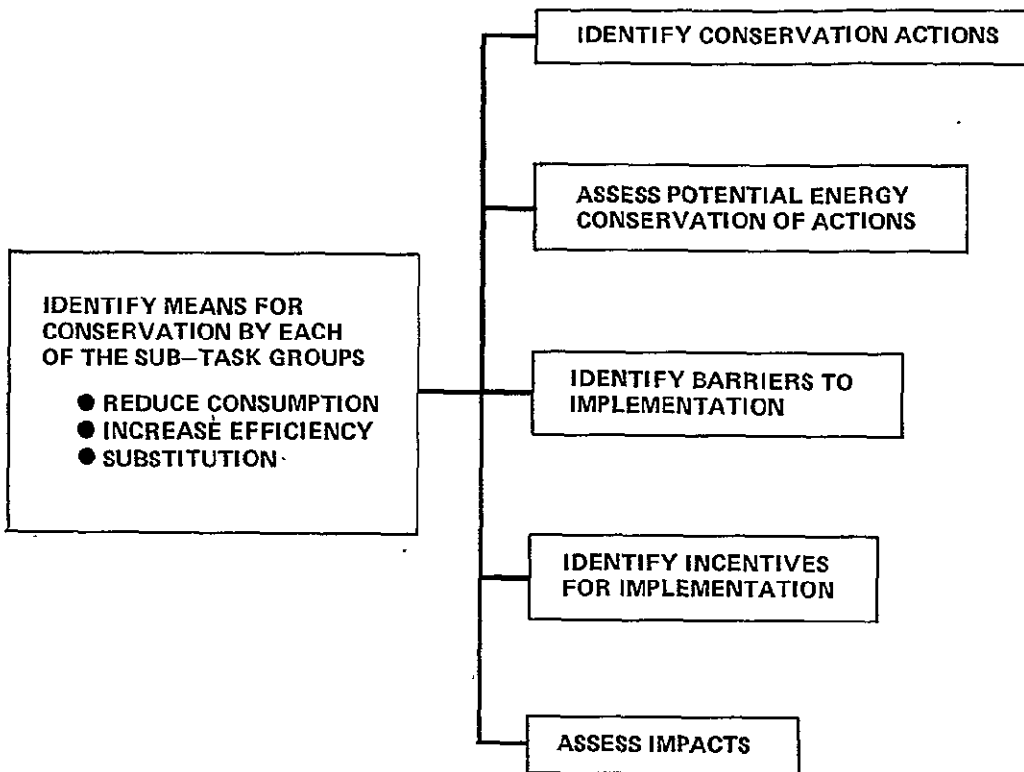


FIGURE G.1.1-1.

SCHEMATIC OF THE THREE SUB-TASK GROUP SYSTEMS APPROACH  
IN THE RESIDENTIAL/ COMMERCIAL SECTOR

TABLE G.1.1-1 CONSERVATION ACTION EVALUATION MATRIX

CONSERVATION ACTION	POTENTIAL SAVINGS	EASE OF IMPLEMENTATION	AVAILABILITY			IMPACTS				OVERALL POTENTIAL	COMMENT
			CAPITAL	MANPOWER	MATERIALS	SOCIAL	POLITICAL	ECONOMIC	ENVIRONMENTAL		
Reduce thermostat setting to 68° in winter	+M	+M	+H	+H	+H	-L	+M	+H	+H	+M	Residential saving 550 x 10 <sup>6</sup> BTU to 670 x 10 <sup>6</sup> BTU, or 30-40 dollars per unit. Total potential saving 2.07 quads. Requires no money, material or manpower. Implementation depends on educational programs and financial incentives. Impacts on utility load factor. Can be instituted immediately and be effective in the near term.
Raise thermostat setting to 78° in summer	+L	+M	+H	+H	+H	-L	+M	+H	+H	+L	Easy to implement. Total potential annual savings 1.066 Q and assumed achievable savings of .522 Q. No investment required. Also impacts on utility load factor.
Alter the night thermostat setting to 60°F at night (8 hrs.)	+M	-L	+L	+L	-L	+L	-L	+L	+M	+L	Total potential annual savings 1.15 Q but assumed achievable savings only .273 Q. Impacts in utilities, bedding manufacturers, users. Increasing fuel costs are incentive for action.
*Potential savings for both Residential and commercial sectors are combined in some cases											

"+" Favorable or positive  
 "-" Unfavorable or negative  
 "H" High  
 "M" Medium  
 "L" Low  
 " " No effect

TABLE G.1.1-1 CONSERVATION ACTION EVALUATION MATRIX (con't)

CONSERVATION ACTION	POTENTIAL SAVINGS	EASE OF IMPLEMENTATION	AVAILABILITY			IMPACTS				OVERALL POTENTIAL	COMMENT
			CAPITAL	MANPOWER	MATERIALS	SOCIAL	POLITICAL	ECONOMIC	ENVIRONMENTAL		
Add insulation at ceilings to R-19 value	+M	-L	+L	+L	-L	+L	-L	+L	+M	+L	Impact on suppliers and installers. Requires moderate investment for payback in 10 years or less. Saturation of potential will be slow if at all and not be effected before 1985. Total potential annual savings 1.27 Q, assumed achievable savings only .378 Q.
Add insulation at exterior walls to R-11 values	+M	+L	+L	+L	-L	+L	-L	+L	+M	+L	Potential savings .513 Q/yr., assumed achievable savings only .013 Q/yr. Not considered to be applicable to existing housing and only limited existing commercial application. Impacts on materials supply and requires money. Most likely incentive is money. Implementation by code.
Install storm windows, double glazing or high efficiency glass.	+M	+L	+L	+L	+L	" "	+L	+L	+L	+L	Save 5 to 6 dollars/window over winter season for an investment of 15 to 20 dollars per window. Fairly quick recovery possible. Total potential savings .621 Q/yr. assumed achievable savings .074 Q. Impacts of money and materials manufacturers.

TABLE G.1.1 -1 CONSERVATION ACTION EVALUATION MATRIX (con't)

CONSERVATION ACTION	POTENTIAL SAVINGS	EASE OF IMPLEMENTATION	AVAILABILITY			IMPACTS				OVERALL POTENTIAL	COMMENT
			CAPITAL	MANPOWER	MATERIALS	SOCIAL	POLITICAL	ECONOMIC	ENVIRONMENTAL		
Insulate hot water pipes	+L	+L	+L	+L	+L	" "	" "	" "	" "	+L	Cost of insulation is barrier, considering potential savings. As part of a retrofit program it contributes savings.
Keep heat transfer surfaces in water heater clean.	+L	-L	+L	+M	+H	" "	" "	" "	+L	+L	Allows efficient conductive heat transfer into water. Potential savings small. Quickly implemented.
Install heat pumps in homes in lieu of electric heating..	+M	+M	+H	+H	+H	+L	+M	-L	+H	+M	Reduced energy consumption for space heating. High C.O.P. Time frame 1975-85. Requires consumer education program. Potential savings to be realized by 1985, .4 quads. Favored in new construction
Install hot water management systems	+M	+L	+M	+M	+M	" "	" "	+M	+H	+M	A variety of low water usage appliances - dishwashers, showers - coupled with improved water heaters utilizing dual tank concept and timers could save 200,000 barrels of oil and gas/day. Assume 1/4 of the residences used such devices at savings of 50%/residence

## G.1.1-1 CONSERVATION ACTION EVALUATION MATRIX (con't)

CONSERVATION ACTION	POTENTIAL SAVINGS	EASE OF IMPLEMENTATION	AVAILABILITY			IMPACTS				OVERALL POTENTIAL	COMMENT
			CAPITAL	MANPOWER	MATERIALS	SOCIAL	POLITICAL	ECONOMIC	ENVIRONMENTAL		
Mandate government standards for lighting in all new and existing commercial buildings. (50-30-10 foot candles std.)	+H	+M	+H	+H	+H	+L	-L	+L	+L	+H	.65 Quads. or 50% savings. Requires government action.
Make wide use of Shade trees.	-H	+M	-L	-L	+L	+H	+M	+L	+M	-H	Not effective in the near term unless trees are existing.
Eliminate gas pilot lights on ranges, furnaces and water heaters	+M	+L	+M	+M	+M	" "	" "	+M	+H	+L	Approximately 8% of total residential natural gas is used by pilot lights when the burners are off. Replacement w/reliable and inexpensive lighter. The savings equal $116 \times 10^{10}$ BTU/day.
Develop integrated utility systems.	+M	=M	-L	-L	-L	-H	-L	" "	+M	-L	Idealized utility system generates electric power and use recovered heat for other functions such as space heating and cooling, water processing and storage drying. Waste could be used as a supplementary energy source. All utilized in 10% of commercial and residential buildings by 1985 at a 40% savings/building. Total savings equal $116 \times 10^{10}$ BTU/day.

### G.1.2. LIST OF CONSERVATION ACTIONS

One major consideration of the residential/commercial task group was the identification of conservation actions related to the sector. As related previously, a large number of these actions were qualitatively assessed as to ease of implementation, potential savings, requirements, impacts, etc. in order to initially determine those few that merit further consideration. Although the list is long, it is not inclusive. It does serve as an overview of possible actions within the sector. Many of these actions are taken from the booklet "Energy Conservation Design Guidelines for Office Buildings" [GSA-74] and "National Petroleum Council Report on Energy Conservation". [NPC-74]

#### Individual Conservation Actions Related to Residential/Commercial Sector

---

Use deciduous trees for their summer sun shading effects and wind break for buildings up to three stories.

Use conifer trees for summer and winter sun shading and wind breaks.

Cover exterior walls and/or roof with earth and planting to reduce heat transmission and solar gain.

Shade walls and paved areas adjacent to building to reduce indoor/outdoor temperature differential.

Reduce paved areas and use grass or other vegetation to reduce outdoor temperature build-up.

Use ponds, water fountains, to reduce ambient outdoor air temperature around building.

Collect rain water for use in building.

Locate building on site to induce air flow effects for natural ventilation and cooling.

Orient buildings to minimize wind effects on exterior surfaces.

Select site with high air quality to enhance natural ventilation.

Select a site that has topographical features and adjacent structures that provide desirable shading.

Select a site that allows optimum orientation and configuration to minimize yearly energy consumption.

Select site to reduce specular heat reflections from water.

Utilize sloping site to partially bury building or use earth berms to reduce heat transmission and solar radiation.



Use minimum ratio of window area to wall area.

Use double glazing.

Use triple glazing.

Use double reflective glazing.

Manipulate east and west walls so that windows face south.

Use window frames that form a thermal bridge.

Allow direct sun on windows November through March.

Use operable thermal shutters which decrease the composite "U" value to 0.1.

Use storm sash or high efficiency glass.

Shade windows from direct sun April through October.

Consider the use of the insulation type which can be most efficiently applied to optimize the thermal resistance of the wall or roof; for example, some types of insulation are difficult to install without voids or shrinkage.

Protect insulation from moisture originating outdoors, since volume decreases when wet.

Use insulation with low water absorption and one which dries out quickly and regains its original thermal performance after being wet.

Where sloping roofs are used, face them to the south for greatest heat gain benefit in the wintertime.

Use permanently sealed windows to reduce infiltration in climatic zones where this is a large energy user.

Where codes or regulations require operable windows and infiltration is undesirable, use windows that close against a sealing gasket.

Group service rooms as a buffer and locate at the north wall to reduce heat loss or the south wall to reduce heat gain, whichever is the greatest yearly energy user.

Use corridors as heat transfer buffers and locate against external walls.

Locate rooms with high process heat gain (computer rooms) against outside surfaces that have the highest exposure loss.

Use landscaped open planning which allows excess heat from interior spaces to transfer to perimeter spaces which have a heat loss.

Group rooms in such a manner that the same ventilating air can be used more than once, by operating in cascade through spaces in decreasing order of priority, i.e., office-corridor-toilet.

In climate zones where outdoor air conditions are close to desired indoor conditions for a major portion of the year, consider the following:

Adjust building orientation and configuration to take advantage of prevailing winds.

Use operable windows to control ingress and egress of air through the building.

Adjust the configuration of the building to allow natural cross ventilation through occupied spaces.

Utilize stack effect in vertical shafts, stairwells, etc., to promote natural air flow through the building.

Reduce ceiling heights to reduce the exposed surface area and the enclosed volume.

Increase the density of occupants (less gross floor area per person) to reduce the overall size of the building and yearly energy consumption per capita.

Spaces for similar functions located adjacent to each other on the same floor reduce the use of elevators.

Increase window size but do not exceed the point where yearly energy consumption, due to heat gains and losses, exceeds the saving made by using natural light.

Where steam is available, use turbine drive for large items of equipment.

Use heat pumps in place of electric resistance heating.

Match motor sizes to equipment shaft power requirements and select to operate at the most efficient point.

Maintain power factor as close to unity as possible.

Reduce length of cable runs.

Increase conductor size within limits indicated by life cycle costing.

Use high voltage distribution within the building.

Match characteristics of electric motors to the characteristics of the driven machine.

Design and select machinery to start in an unloaded condition to reduce starting torque requirements. (For example, start pumps against closed valves.)

Use direct drive whenever possible to eliminate drive train losses.

Use high efficiency transformers (these are good candidates for life cycle costing).

Use liquid-cooled transformers and captive waste heat for beneficial use in other systems.

In canteen kitchens, use gas for cooking rather than electricity.

Use conventional ovens rather than self-cleaning type.

Utilize a sloping site to accommodate entrances on multi-levels to reduce elevator mileage.

Use elevators rather than escalators for vertical travel.

For high traffic densities through one or two floors, use staircases or ramps rather than escalators.

Use solid state controls for elevators.

Reduce the number of elevators installed by scheduling their use for essential purposes only (for example, stops at every other floor would eliminate single floor trips and enforce use of staircases).

Install on-site waste heat recovery incinerators for disposal of solid wastes. The waste heat can be used for space heating, ventilation, water absorption, refrigeration or other thermal uses.

Separate and salvage usable materials which have a commercial value. Re-cycling many materials consumes less raw source energy than producing virgin materials and could have economic benefits as well.

In areas requiring it, consider the use of solid waste for composting.

Use outdoor air for sensible cooling whenever conditions permit and when re-captured heat cannot be stored.

Use adiabatic saturation to reduce temperature of hot, dry air to extend the period of time when "free cooling" can be used.

In the summer when the outdoor air temperature at night is lower than indoor temperature, use full outdoor air ventilation to remove excess heat and pre-cool structure.

In principle, select the air handling system which operates at the lowest possible air velocity and static pressure.

Design air handling systems to circulate sufficient air to enable cooling loads to be met by a 60°F air supply temperature and heating loads to be met by a 90°F air temperature.

Design HVAC systems so that the maximum possible proportion of heat gain to a space can be treated as an equipment load, not as a room load.

Schedule air delivery so that exhaust from primary spaces (offices) can be used to heat or cool secondary spaces (corridors).

Design duct systems for low pressure loss.

Use high efficiency fans.

Use low pressure loss filters concomitant with contaminant removeable.

Use one common air coil for both heating and cooling.

Reduce or eliminate air leakage from duct work.

Limit the use of re-heat to a maximum of 10% gross floor area and then only consider its use for areas that have atypical fluctuating internal loads such as conference rooms.

Design chilled water systems to operate with as high a supply temperature as possible -- suggested goal -- 50° (this allows higher suction temperatures at the chiller with increased operating efficiency).

Use modular pumps to give varying flows that can match varying loads.

Exhaust air from center zone through the lighting fixtures and use this warmed exhaust air to heat perimeter zones.

Design HVAC systems so that they do not heat and cool air simultaneously.

Select high efficiency pumps that match load. Do not oversize.

Design piping systems for low pressure loss and select routes and locate equipment to give shortest pipe runs.

Adopt as large a temperature differential as possible for chilled water systems and hot water heating systems.

Consider operating chillers in series to increase efficiency.

Extract waste heat from boiler flue gas by extending surface coils or heat pipes.

Select boilers that operate at the lowest practicable supply temperature while avoiding condensation within the furnaces.

Use unitary water/air heat pumps that transport heat energy from zone to zone via a common hydronic loop.

Use thermal storage in combination with unit heat pumps and a hydronic loop so that excess heat during the day can be captured and stored for use at night.

Use heat pumps both water/air and air/air if a continuing source of low-grade heat exists near the building, such as lake, river, etc.

Provide all outside air dampers with accurate position indicators and insure dampers are airtight when closed.

Use spot heating and/or cooling in spaces having large volume and low occupancy.

Use electric ignition in place of gas pilots for gas burners.

Use a total energy system if the life cycle costs are favorable.

Turn off pilots in gas furnaces.

Use chilled water storage systems to allow chillers to operate at night when condensing temperatures are lowest.

Locate cooling towers or evaporative coolers so that induced air movement can be used to provide or supplement garage exhaust ventilation.

Use modular boilers for heating and select units so that each module operates at optimum efficiency.

Use solar energy via a system of collectors for heating in winter and absorption cooling in summer.

Minimize requirements for snow melting to those that are absolutely necessary and, where possible, utilize waste heat for this service.

Reduce hot water generating and storage temperature to the minimum required for hand washing (to 120°).

Avoid the use of straight electric heating for hot water, consider instead using a heat pump.

For hot water piping and storage tanks, if used, increase the amount of insulation or select one with better "R" value.

When storage tanks are used, locate them as close to the point of usage as possible.

Provide control to automatically shut off recirculating pumps during weekends, nights and periods of the day which are well-defined, when hot water usage is light.

To reduce the quantity of hot and cold water used:

Select kitchen equipment such as dishwashers that have minimum water requirements.

Use a single system to meet handwashing needs in toilets.

Use spray type faucets with flow restrictors.

Use self-closing valves to control faucets.

Use well water, if available.

Use waterless or low volume flush water closets.

Where fresh water is in short supply, consider the use of solar stills.

Select a water treatment system for cooling towers that allow high cycles of concentration (suggested target greater than 10:7) and reduces blowdown quantity.

Schedule boiler blowdown on air "as needed" basis rather than a fixed timetable.

Re-cycle waste water for toilet flushing.

Use restricted flow shower head (2.5 gal/min. maximum flow).

Boost hot water temperature locally for kitchens, etc., rather than provide higher temperatures for the entire building.

If boilers are used as primary heat source for domestic hot water, install a boiler to match the load rather than use an oversized heating boiler all summer. (Careful selection of modular heating boiler sizes could achieve the same end.)

Use gravity circulation for domestic hot water rather than pumps.

Arrange circulating pipework to minimize length of dead legs connecting to faucets (this saves water as well as energy as it eliminates the need to draw off quantities of cold water before hot water can be obtained.)

Meeting hot water heating needs from the following sources:

Waste heat from incinerators.

Rejected heat of compression from refrigeration units (both air conditioning and kitchen freezers and cold rooms).

Hot condensate return from steam operated systems.

Rejected heat from diesel or gas engines.

Waste heat from drains used in conjunction with heat pumps.

Waste heat from transformers.

Consider the use of solar heaters using flat plate collectors with heat pump boosters for winter.

Heat building to no more than 60°F when unoccupied.

Cool building to no less than 78°F when occupied.

Do not cool building when it is unoccupied.

Schedule morning start up in winter so that the building is at 63°F when occupants arrive and warms up to 68°F over the first hour.

Limit pre-cooling start-up in morning to give building temperature of 5°F less than outdoor temperature or 80°F, whichever is highest.

Close outdoor air dampers for the first hour of occupancy whenever outdoor air has to be either heated or cooled.

Close outdoor air dampers for the last hour of occupation whenever outdoor air has to be either heated or cooled.

Turn off heating or cooling 30 minutes before the end of the occupied period.

Close outdoor air dampers for 10 minutes in every hour (adjust time period according to experience).

Allow humidity to vary naturally in the building between 20% RH and 65% RH. Only add or remove moisture when building conditions exceed those limits.



### G.1.3. EXAMPLES OF FEDERAL AND STATE LEGISLATION PERTAINING TO ENERGY CONSERVATION IN THE RESIDENTIAL AND COMMERCIAL SECTOR

#### Federal Bills

H.R. 3849 Housing -- low interest loan program -- insulation and heating equipment

To establish in the department of Housing and Urban Development a direct low interest loan program to assist home owners and builders in purchasing and installing solar heating (or combined solar heating and cooling) equipment.

S 349 Energy Labeling and Disclosure Act

To contribute to an alleviation of the energy crisis by providing American consumers with information on the energy characteristics and the financial cost associated with the use of major household products and automobiles.

S 1149 To provide for a national fuels and energy conservation policy, to establish a national energy conservation program. Title VI -- "Energy efficient lighting, appliance and space heat systems" affects the residential and commercial sector.

H.R. 7014 Energy Conservation and Oil Policy Act of 1975. Title V Part B Energy Labeling and Efficiency Standards for Consumer Products Other than Automobiles is concerned with energy conservation in the residential and commercial sector.

S 1392 Energy -- Conservation -- demonstration program.

To establish a demonstration program in energy conservation using promising innovative technology to the maximum extent possible, through retrofitting existing buildings with energy conservation equipment and systems.

#### State Legislation

Montana - H 663

Encourages investment in non-fossil forms of energy generation and in energy conservation in buildings through tax incentives and capital availability.

New Mexico - H 395	Provides that a feasibility study of the energy source for heating and air conditioning must be made before any contract is executed for the construction or major alteration of a state building.
North Carolina - SR 149	Conservation of energy through the North Carolina Building Code.
Oregon - S 283	To provide maximum energy conservation in design, construction and repair of buildings.
Texas - S 516	Relates to energy conservation in certain buildings.

## G.2. REDUCING CONSUMPTION AND INCREASING EFFICIENCY OF BUILDINGS

This section includes a description of the approach taken by the efficiency sub-task group and an assessment of two conservation actions.

### G.2.1. DEFINITION AND DESCRIPTION

Efficiency is conceived as achieving a reduction in input without reducing result (output). In terms of energy, improved efficiency may be simply a furnace that maintains the desired temperature while using less fuel. On a larger scale, a building may be more efficient as the result of one or more actions; the result of which is less use of energy at no change in the environment of the building. In the same manner, more efficient communities may be developed.

The building industry influences, by its decisions, nearly one-third of the energy used. If building process and function decisions are made with the added concern for conservation of energy, considerable savings should be possible.

Energy use in buildings is essentially a factor of physical design, construction practices, and occupant needs and practices. If we consider that buildings provide controlled environments for people to live in latitudes which are too hot, too cold, too bright, or too dark, then an obvious use of energy in buildings is in maintaining a livable environment. Building design, including the climate modification systems, can respond with more efficient homes, shops, and offices. In the same vein, the practices and standards of construction and what are identified as user needs require close examination. We should look at the ability, the opportunity, and the responsibility of the planner, developer, banker, designer, builder, and user to bring about energy conservation in buildings and communities. Current practices based on excessive standards, cheap materials, insufficient supervision, and a low first cost syndrome must be examined with the intention of erecting and operating a more energy efficient building.

### G.2.2. DISCUSSION OF THE APPROACH (FIGURE G.2.2-1)

The requirements for developing means of conservation by increasing efficiency in the residential/commercial sector include the need:

- To identify conservation actions

- To assess the potential energy conservation of the actions

- To identify any barriers to implementation of the actions

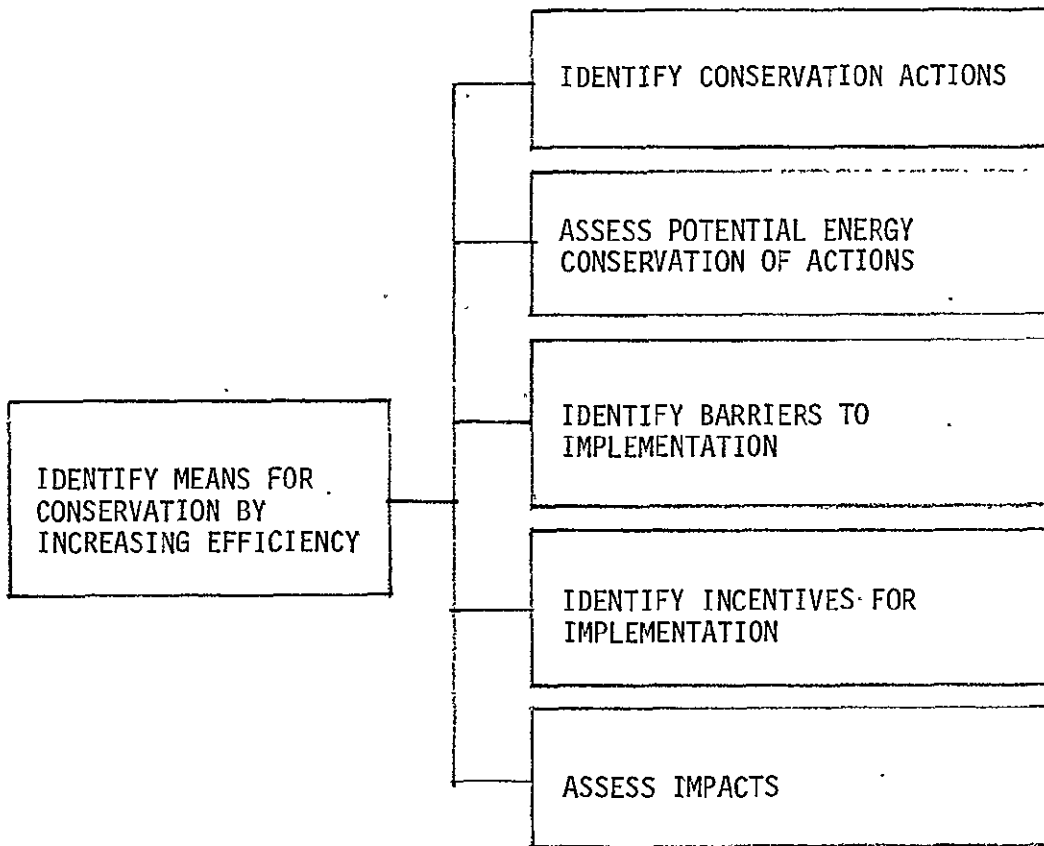


FIGURE G.2.2-1 SCHEMATIC OF "INCREASED EFFICIENCY" SUB-TASK GROUP SYSTEMS APPROACH

To identify incentives to implementation of the actions

To assess the impacts of the actions

In each of these requirements, it is necessary to identify:

Methods or mechanisms of acquisition which give us the material to be examined.

Constraints and criteria, the sieve which separates the relevant material out of that collected.

A display technique by which that final relevant material can be communicated.

Each of the requirements is discussed in detail below.

#### Identify Conservation Actions.

To identify conservation actions involves knowing two things.

How the energy is used in a building.

What are the determinants to its use.

Knowing that energy is used for space heating, cooling, water heating, lighting and equipment heating, suggests areas for investigation. If there are other end uses, they need to be known. In the same manner, knowing the mode of use, the standards, the capabilities of materials and the environmental circumstances and analyzing the two knowns together suggests alternatives which become potential actions if they satisfy the controls that are applicable. Two basic controls exist:

Technical feasibility

Social acceptability

Any idea must be feasible technologically as it relates to conservation and not violate the established institutional constraints.

### Assess Potential Of Conservation Actions

Assessment of the potential energy conservation of the actions is dependent on:

Establishing the potential energy savings

Observing the resource requirements

Observing the time for implementation

At best these will include some intelligent guesses for the most part. Comparisons, computations and example measurements indicate trends and possibilities. Controls in this instance are in addition to the previous ones:

Availability of resources required

Base of reference

Obviously any assessment must be in relation to a base (time or something else), and available supplies of money, manpower or materials must be considered.

### Barriers And Incentives To Implementation

Barriers and incentives appear in relation to each action as the process of implementation interfaces with social and technological controls. Some actions may be incentives.

### Assessing Impacts

A study of impacts requires knowing:

Where and what are impacts?

What is the effect of an impact?

Is the impact acceptable?

The fact that actions impact on people, resources, institutions, and other actions suggests a complex analysis if the interface is anything but a simple relationship.

### G.2.3. POTENTIALS FOR CONSERVATION

The American Institute of Architects [AIA-74] have identified thirteen

categories under the heading of physical design which influence the energy use of a building. While recognizing many of these same determinants, Richard G. Stein [AF-73] points out more explicitly the need to re-examine building standards and codes and the opportunities for energy costing of materials and construction processes. The implementation of life cycle budgeting by the General Services Administration recognizes the total use of energy and encourages its wise use.

In the studies of potential energy conservation in the residential/commercial sector, both the National Petroleum Council [NPC-74-1] and Project Independence [PI-74-5] emphasize actions that are in response to weaknesses in existing buildings. This is a very obvious need. Even so, a wide saturation of the available market is not expected. These weaknesses are important areas of concentration because they represent major quantities of energy consumption to be reduced with moderate or no investment of money.

When the reports apply the same actions to new construction, the implication is that only a few areas are subject to relevant actions in both instances. There is a considerable difference between retrofitting a building in which all the determinants of energy use are set, and designing a new building in a manner both sensitive and responsive to the conditions which will determine its energy use.

Both reports fall short in identifying actions as they relate to energy conservation in buildings. The limitations of "immediate results" is most likely the cause. In the short term, and as they concern existing buildings, the actions are well chosen.

Buildings are unique in their location and relationship to the environment. The circumstance of climate and solar conditions vary at macro and micro scales. Failure to analyze this relationship can be costly. Buildings are unique in the way they are used. The number of occupants, the kinds of activities, the time of use, the facilities provided, the equipment installed and the conditions of comfort are different in one or more combinations which belie a universal calculation or standard for all.

It would be well to consider a building as a system consisting of subsystems and components, each with specific functions, and yet an integral part of the system when identifying actions. The representative list of activities included in this appendix, drawn mainly from General Services Administration [GSA-74], illustrates the possible range of opportunities for actions.

A more detailed discussion of energy use in buildings will examine physical design as one determinant, construction practices and standards as another and the users needs and operations of buildings as a third determinant of energy use.

### G.2.3-1 PHYSICAL DESIGN

Under physical design are the elements discussed below.

#### Site Analysis

Relate buildings to the peculiar site conditions of topography, climate, shape, orientations, soil, vegetation and adjacent elements to the extent that their potential for energy conservation be recognized and used. The length and nature of seasons, temperatures, precipitation amounts and occasions, the sun's intensity, direction, the breadth of its swing and the duration of its exposure, the velocity and direction of prevailing winds, the hills and valleys, trees and water are all elements that may have an influence on energy consumption in buildings.

#### Building Orientation

With regard to sun path and intensity, prevailing wind, and orientation of the building, its windows and its doors will determine the solar gain and the infiltration for a specific building in a given time and place.

#### Configuration

Thermal transmission is a function of surface area. Physical forms that offer a high volume of usable space per square foot of surface are energy efficient. The effect of shapes of buildings singly and in concert on air flow is seen in the infiltration level also.

#### Envelope

The envelope includes the building skin and as such has a capability for thermal transmission and storage. Indigenous architecture of the south-west or near east responds to climate effectively with walls that store and transmit available heat usefully. Building skin density is the key factor. Materials in various combinations determine the heat flow rate.

If materials used are selected on the basis of conservation, they must be examined for energy use from source of raw material to in place and operation.

Glass is the single most ineffective barrier to thermal transmission in a building. Glass is the material of windows and the means of getting natural light into buildings. The size and placement of glass is critical as is the type used. There is tinted glass, coated glass, heat absorbing glass and multi-paned glass, all of which are useful in controlling heat transmission and natural light.



Another item useful for residential sash is the storm window. Where windows occur exposed to sun, various exterior or interior shading devices will control solar gain. Thermal barriers will prevent much unwanted transmission of heat.

Weather stripping of doors and windows helps to eliminate undesirable infiltration through the cracks of joints, and window sash which bridge through the wall should be of material low in conductivity.

Insulation is a principal means of affecting energy flow through the skin of buildings. The choice of materials, the location and amount, and the quality of application are concerns to be studied.

In the light of experience, we know that caulking of cracks in frames and joints will reduce the amount of infiltration.

### Space Planning

Room size and configuration must be determined by its use to avoid over-sizing and over-building. Size of spaces may anticipate a variety of arrangements by becoming one space. The result is to simplify the air distribution and lighting problem. Zoning of activities allows more efficient climate control also.

### Space Heating

Fuel consumption for heating is the largest energy user in the residential and commercial sector. The amount of heat that must be provided is a function of several factors including:

Thermal transmission through the building skin

Wind velocity

Air infiltration

Ventilation

Occupancy

Lighting and machinery

The building and its heating unit can be designed for high efficiency if all of these factors are taken into account. The heating efficiency of the building itself can be increased by increasing the amount of insulation, reducing infiltration by caulking, and by situating the house to take

maximum advantage of solar heat gain. Additional savings may be realized by increasing the efficiency of the heating unit. Typical gas and oil furnaces have efficiencies (first law) of 70% and 60% respectively for the transfer of chemical energy in the fuel to heat energy in the heat transfer medium (water, steam or air). The heat distribution system accounts for additional losses with a large portion of the heat added transferred sideways through uninsulated ducts or pipes. Only a portion of the energy leaking out helps to heat the building, with the remainder delivered to unused areas, to spaces between the wall studs, and ultimately to the outside. Insulation of the ducts is a conservation action which should be investigated. Regular maintenance performed on the furnace will also increase its efficiency as will cleaning of filters to reduce functional losses in the distribution system.

Electricity can also be used as a heating source. There are three principal methods of using electricity for heating.

Central resistive coil that heats a heat transfer fluid

Resistive baseboard or floor heating throughout the house

An electric heat pump

The first of these methods has the losses associated with electricity generation as well as duct distribution losses, yet it is frequently used. The second method offers convenience, simplified zone control and low initial cost, but still has the losses associated with power generation. The third electrical sources uses electrical energy more efficiently than pure resistive heating and may use ground water or be solar assisted. This third method of electrical heating is being recommended more and more now that heat pump reliability has been proven.

Yet another option must be considered when thinking in terms of increasing the efficiency of heating a building. Space heating requires low grade energy and therefore may be accomplished with waste heat if available. Even if waste heat is of too low a grade to be used directly for heating, it may be used as the low temperature source for a heat pump cycle and thereby increase the performance of such a system considerably.

### Cooling

Air conditioning accounts for less than 3% of the total national energy consumption, but is a much higher portion during the summer months. It is the major reason for the shift in the peak electricity consumption from Winter to Summer. The amount of heat which must be removed from a building,

the cooling load, depends on several factors as does the heating load. Some of these factors are:

- Heat gain through walls and roof

- Solar gain through windows

- Air infiltration

- Outside and inside humidity

- Ventilation

- Internal heat load due to:

  - Machinery

  - Lights

  - People

The cooling efficiency of the building itself can be increased by designing its fenestration and situating it such that solar heat gain through the windows is minimized. Air infiltration and ventilation can also be reduced to increase the efficiency of the building -- cooling system combination. The design of the cooling system can result in more efficient operation by:

- Designing for 5 percent outdoor air conditions rather than 2.5 percent.

- Using an economizer cycle which senses the outside air enthalpy and inducts fresh air when it is advantageous to do so.

- Using higher efficiency equipment.

- Using the rejected energy for reheat or space heating of some other part of the building.

One area where new technology might make a contribution to increased efficiency is in the design of the heat exchangers for lower temperature gradients at the condenser and evaporator. Cooling storage systems can result in higher efficiency and energy savings by allowing a unit that is smaller than that necessary to provide peak load cooling to provide off peak cooling around the clock. Peak cooling is provided by the storage unit which has been "charged" during off peak hours.

## Lighting

Lighting consumes 20 percent of U.S. electric energy; thus, lighting uses 5 percent of all U.S. energy. Two-thirds of the lighting energy is used by incandescent lamps and one-third by fluorescent and vapor lamps. Fluorescent and vapor lights produce approximately four times as much useful light per unit energy input as incandescent lamps and supply about two-thirds of the useful light. This suggests that a large lighting energy savings could be realized by increasing the efficiency of our lighting systems - switching from incandescent to fluorescent lamps. The largest commercial savings of lighting energy would be to use the available light more efficiently by supplying bright light only where it is needed rather than uniformly illuminating an entire floor. As the position, angle and distance of a light source in relation to a task area also affects lighting efficiency, these factors should be considered when designing or redesigning a system. The overall lighting efficiency of the building should also be considered, i.e. balancing the use of natural light against increased heat transmission or infiltration losses and designing spaces in a building such that similar task areas are grouped or stacked to maximize the efficiency of the lighting and wiring system.

## Ventilation

Ventilation is the controlled induction of fresh air into a building for the purpose of providing healthful air quality - replacement of stale air, dilution of odors and impurities. It has a direct effect on energy consumption because the air inducted has to be cleaned, humidified or dehumidified, heated or cooled, and moved, all of which require expenditure of energy. Ventilation can be accomplished naturally, mechanically or through a combination of the two. Natural ventilation requires the expenditure of no energy to accomplish it, but may lead to increased heating or cooling loads. It requires operable windows, but is most energy efficient where it is applicable. In areas where air temperatures and changes in air quality are not extreme, natural ventilation can be used to advantage and the building should be situated and designed to maximize its utility.

Mechanical ventilation is required where natural ventilation is insufficient or undesirable. In commercial buildings ventilation is designed according to empirical rules which were established many years ago when energy was cheap. Recent studies indicate that in many cases the ventilation specified far exceeds that actually required. The efficiency of a given ventilation system could be increased by:

- Determining air quality, including moisture content and level of impurities and adjusting the fresh air induction accordingly.

- Avoiding over-sizing the system by considering the infiltration rate in the analysis preceding installation.

Grouping or stacking areas in need of high level ventilation away from those that don't.

Using filters to rehabilitate air quality.

Establishing ventilation zones within a building to avoid ventilating areas with low occupancy.

Restricting smoking to designated high ventilation areas away from the heavily populated areas.

### Movement Systems

Elevators, escalators, and walking are the principal means of movement in building. The arrangements and elimination will make a difference in energy use.

### Electric Power

Building transformers and distribution systems are subjects of investigations as are load shedding devices, power storing systems, and motor power factors. On-site electrical generation for a building which reuses its own waste heat can sometimes save energy. The feasibility of such a system which is also generating heating and cooling and hot water for the building depends on a continuous, simultaneous and balanced demand of heating/cooling and electrical energy.

A further development of the total energy concept is an integrated utility system in which all the utilities are combined into a single function. The system provides, besides electric power and heating/cooling, water and waste collection in the operation, thereby achieving a more complete utilization of energy and materials than in the separate functions. The same limitations of continuous, simultaneous and balanced demands are essential to success.

### Domestic Hot Water

In residences and hospitals, hot water is a significant energy user. Pumping and processing water are the means of energy use; therefore, reducing use and lowering temperatures of water will reduce energy.

## Waste Management

Liquid Waste - energy savings can accrue from such processes as using waste heat from nearby power plants for liquid waste treatment. The sludge from liquid waste treatment can be dried and used as fuel to generate electricity. Treated effluent can be used to provide cooling water for power plants, and recovered heat from refuse incinerators can be used for central heating and cooling systems, or for generating electricity. The recovered heat from hot water drains in apartments and hospitals can be used to preheat domestic hot water systems.

Using tank-type water closets or vacuum-flush systems, instead of flush-valve models, can reduce the flow of water and, therefore, the energy required to pump it. The standard five-gallon flush should also be re-examined. "Sovent" plumbing systems, or other similar innovations, eliminate separate aeration pipes for toilets. All such options should be studied as they apply or do not apply to a specific building project.

Solid Waste - reclamation of solid waste, depending on volume and kind, became a viable conservation measure when organized for one building or a group of buildings.

The amounts of solid waste generated within a building vary greatly, depending on the building's use and number of occupants. Common estimates are that an office building generates one or two pounds of solid waste per person per day; a residence generates five or six pounds per person per day; a hospital, up to 20 pounds. Half of solid waste, on the average, is paper and cardboard. This, along with plastics, wood, ferrous metal, aluminum, glass, tar, naphtha, textiles, oil, ash, and foodstuffs, may be recycled.

Treatment, or waste disposal, includes several options. Pyrolysis units can produce gaseous fuel from waste matter by heating it to high temperatures in the absence of oxygen. The waste may be incinerated at the building or elsewhere, and the recovered heat used for hot water or HVAC systems, or as steam to generate electricity. (Incinerators with heat recovery systems that meet government standards for emission are available.) The wastes themselves may be recycled, or they may be compacted to minimize their volume for transportation, storage, or landfill. Shredding devices can aid recycling processes or prepare the organic wastes for disposal through the liquid waste or sewage treatment facilities. The organic wastes may be used to produce methane gas or processed before entering the liquid waste system.

#### G.2.3.2 CONSTRUCTION PRACTICES

Much construction is governed by established conventions, codes, and labor and management practices. Existing codes often discourage innovative systems and new materials which may be energy conserving. Excessive forms for concrete and poor project planning are additional discouragements. On the other hand, a fresh look at materials handling techniques, standards of construction, and labor and materials codes can encourage conservation. Too, a judicious use of factory-built components can go far to eliminate waste and control quality, thereby making construction more energy efficient. Further savings may come from specification by performance, which encourages coordinated systems development.

#### G.2.3.3 OCCUPANT NEEDS AND PRACTICES

Needs are those requirements essential to a physically and mentally healthful life. Practices relate to the manner of use. Cultural differences which encourage different uses are an instance of the latter, while food, shelter and warmth are instances of need. Comfort standards and design temperatures are subject to arbitrary choice. Lighting requirements are set with inadequate physiological study, and adaptability of spaces and facilities is disregarded. Switching of lights is a case in point. Arrangements of switches to encourage a variety of lighting possibilities as determined by users will save energy. Users response to operable windows, and fireplace dampers directly affect energy use. User's selection and operation of appliances can be guided by knowledge of energy cost and maintenance procedures.

Perhaps the most generous use of energy in this category can be controlled through maintenance operations. From changing filters in the individual residence to reducing the night time lighting load in multi-story office buildings, there are a multitude of opportunities. One of the first requirements is to establish a schedule for maintenance. Another is to examine each operation for its conservation potential. Though many actions will appear to be in the nature of curtailing demand rather than increasing efficiency, the result is a more efficient building.

#### G.2.3.4 ASSESSMENTS

There are many variables which influence the effect of specific actions and their choice. Such actions are not always as appropriate for residential construction as for commercial construction, and vice-versa because of different functions. Likewise, the response to specific actions by existing buildings and new construction is different. Then too, the quality of construction is not always consistent with designed capability. Nevertheless,

analysis of each building will identify opportunities for conservation to be pursued. Other requirements for all but a very few actions are money, manpower and materials. The principal barriers to achievement are the cost and the lack of understanding. Implementation requires education of consumers, builders, designers, developers, bankers and investors. It also needs financial incentives for many activities. Specific actions under the general actions of reducing consumption and increasing efficiency of buildings and systems for heating, ventilating and air conditioning fall into three groups:

Those that are operational in nature.

Those relating to physical improvement of buildings.

Those that require major changes in HVAC.

The specific actions of the operations group impact on the consumer who must adjust to environmental changes. In addition, they impact at the market where money not used for energy is spent in other ways. Even though the consumer may be attracted by the savings that are due him, agencies can effect a greater participation through government educational programs, research, and measures which assure the energy saving is reflected in energy cost.

The physical improvement of buildings impinges on the ability of the manufacturer and supplier to meet a demand possibly five to six times larger than at present, and on the consequent need for money by consumers and manufacturers. There may be additional demands for labor. There may be demands for energy. (Glass is energy intensive.) Normal payback would be ten years for insulating, glazing and caulking an average 1500 square foot house. This assumes the quality of installation is equal to design expectations which is not always the case. There are indications that double glazing is not as effective as projected to be in reducing thermal transmission, according to J.M. Fox [PU-73]. These specifications are more apt to be effected in new construction than in existing buildings, though some existing residential structures are adaptable and need them. Building standards and codes are the most effective way of implementation, and governmental action may be required.

The third group of specific actions is concerned with major changes in systems of heating, ventilating and air conditioning, and as such, are the least acceptable activities. Positive financial incentive is necessary. Again, new construction will more readily accept most changes of this kind than existing buildings will. Manufacturers do not indicate any crisis in meeting the demand, but consumers will need funds over and above that normally required.



#### G.2.4 HEAT PUMP ANALYSIS

It was felt that the heat pump would be a good example to investigate in depth, because space heating represents the largest percentage of energy consumption in the residential sector (71.4% of usage in residential sector, 11% of total energy consumption in the United States) and is, therefore, the largest target for energy savings. In addition, projections indicate a tendency toward total electric living units, i.e., homes with electric space heat and air conditioning.

In order to quantify the example it was necessary to make several assumptions. These assumptions are based on information available in published reports, personal communication with people in the space conditioning field and in some cases "educated speculation".

The assumptions underlying the analysis are as follows:

The potential for energy savings by the installation of heat pumps is based on projections that the percentage of electrically heated homes will increase from 10% in 1975 to 24% in 1985. It was assumed that of these new homes 40% would install heat pumps under present market conditions. This would result in a potential for installing heat pumps, rather than resistance heating, in 60% of the new electrically heated home construction.

Heat pumps will be installed in single family rather than in multifamily dwellings because of the difficulty in inducing builders or owners of multifamily dwellings to use life cycle costing, as they usually do not pay the building operating costs, but pass them on to the residents.

The inventories of electrically heated homes in 1975 and 1985 were taken from Table G.2.4-1. [PI-74-5] The 1975 inventory was taken to be half way between the values given for 1970 and 1980.

An average value of  $49.2 \times 10^6$  BTU/year was used as the point of use energy consumption for electric heat throughout the country. This is a weighted average based on unit demand for electric heat in the Northeast, North Central, South and West as shown in Table G.2.4-2. The weighting factor was the percentage of homes in each region that are projected to have central air conditioning in 1985 (see Table G.2.4-3). Values for 1985 were obtained by linear interpolation between 1970 and 1990 values.

TABLE G.2.4-1. RESIDENTIAL INVENTORY [PI-74-5]

(thousand year-round units)

	1970 Inventory	New Construction 1970-80	Removals 1970-80	1980 Inventory	New Construction 1980-85	Removals 1980-85	1985 Inventory	New Construction 1985-90	Removals 1985-90	1990 Inventory
<b>Northeast</b>	16,198	5,354	2,357	19,195	2,770	1,288	20,677	2,540	1,371	21,846
Mobile Home	241	710	201	750	320	150	920	267	165	1,022
Single-Family	7,778	2,186	391	9,573	1,137	227	10,483	1,176	249	11,410
Low-Density	4,552	1,163	1,164	4,551	636	594	4,593	529	605	4,517
Low-Rise	1,392	760	133	2,019	396	110	2,305	327	138	2,494
High-Rise	2,235	535	468	2,302	281	207	2,376	241	214	2,403
<b>North Central</b>	18,675	6,889	3,436	22,128	2,978	1,691	23,415	2,944	1,754	24,605
Mobile Home	499	1,439	322	1,616	559	291	1,884	521	350	2,055
Single-Family	13,261	3,440	1,696	15,005	1,500	750	15,755	1,570	788	16,537
Low-Density	2,773	1,176	739	3,210	534	363	3,376	502	360	3,518
Low-Rise	1,686	507	550	1,643	238	197	1,684	243	163	1,764
High-Rise	456	327	129	654	147	85	716	108	93	731
<b>South</b>	20,884	9,979	4,259	26,604	4,817	2,070	29,351	4,800	2,040	32,111
Mobile Home	869	2,146	460	2,555	893	400	2,988	841	538	3,291
Single-Family	15,683	5,312	2,530	18,465	2,586	1,107	19,944	2,734	997	21,681
Low-Density	2,293	1,514	641	3,166	756	340	3,582	745	337	3,990
Low-Rise	1,698	698	511	1,885	413	110	2,188	332	109	2,411
High-Rise	341	309	117	533	169	53	649	148	59	738
<b>West</b>	11,942	5,352	3,132	14,162	2,656	1,459	15,359	2,269	1,284	16,344
Mobile Home	464	730	312	882	329	176	1,035	236	186	1,085
Single-Family	8,079	2,366	1,725	8,720	1,165	697	9,188	1,096	551	9,733
Low-Density	1,379	1,136	371	2,144	592	228	2,508	469	237	2,740
Low-Rise	1,757	807	624	1,940	411	291	2,060	336	241	2,155
High-Rise	263	313	100	476	159	67	568	132	69	631
<b>U.S. Total</b>	67,699	27,574	13,184	82,089	13,221	6,508	88,802	12,553	6,449	94,906
Mobile Home	2,073	5,025	1,295	5,803	2,101	1,077	6,827	1,865	1,239	7,453
Single-Family	44,801	13,304	6,342	51,763	6,388	2,781	55,370	6,576	2,585	59,361
Low-Density	10,997	4,989	2,915	13,071	2,518	1,530	14,059	2,245	1,539	14,765
Low-Rise	6,533	2,772	1,818	7,487	1,458	708	8,237	1,238	651	8,824
High-Rise	3,295	1,484	814	3,965	756	412	4,309	629	435	4,503

Sources: United States Department of Commerce, *1970 Census of Housing* and Arthur D. Little, Inc.

TABLE G.2.4-2. SINGLE-FAMILY, DETACHED, UNIT DEMAND  
- 1970 (MM BTU/UNIT/YEAR)

		Fuel		
	Stories	Electricity	Gas	Oil
Space Heating:				
Northeast	1	66.2	184.5	215.2
	2	66.3	174.5	203.5
North Central	1	75.4	205.5	239.8
	2	74.9	196.3	229.2
South	1	37.2	84.7	
	2	35.2	81.2	
West	1	48.5	113.1	
	2	48.4	109.4	

TABLE G.2.4-3. AIR CONDITIONING PENETRATIONS (Percent  
of Total) [PI-74-5]

Region	1970			1990		
	Room	Central	Total	Room	Central	Total
Northeast	27	4	31	53	28	81
North Central	25	9	34	47	38	85
South	34	18	52	25	75	100
West	14	10	24	36	54	90

The coefficient of performance, defined as:

$$\text{COP} = \frac{\text{heat delivered to the conditioned space}}{\text{energy input required}}$$

was taken to be 2.25 on the average over the ten year period. This is based on projections that a high percentage of the units will be installed in the south where values are in many cases greater than 2.5, plus the projections that heat pump COP will increase on the average from 50% to 100% over the next 10 years.

Air conditioning energy demand is equal for the heat pump and electrically driven air conditioning unit installed in all homes.

### Analysis

10% of single family inventory in 1975 =  $4,830 \times 10^3$  units

24% of single family inventory in 1985 =  $\underline{13,300 \times 10^3}$  units

Electrically heated homes to be built  
in period 1975-1985  $8,470 \times 10^3$  units

Number of dwellings with potential for installation of heat pumps (assumption 1) =  $(.60) (8470 \times 10^3) = 5.1 \times 10^6$  units

If these  $5.1 \times 10^6$  homes were heated with electric resistance furnaces, the point of use energy requirement would be  $(5.1 \times 10^6) \times (49.2 \times 10^6 \text{ BTU/yr}) = 2.5 \times 10^{14} \text{ BTU/yr}$ . Assuming the conversion and distribution loss will average 67%, this is equivalent to  $7.5 \times 10^{14} \text{ BTU/yr}$  primary energy consumption. If these  $5.1 \times 10^6$  homes were instead heated with heat pumps, the energy required (assumption 5) would be:

$$\begin{aligned} \text{primary energy input to heat pumps} &= \frac{7.5 \times 10^{14} \text{ BTU/yr}}{2.25} \\ &= 3.3 \times 10^{14} \text{ BTU/yr} \end{aligned}$$

This represents a potential savings of  $(7.5-3.3) \times 10^{14} = 4.2 \times 10^{14} \text{ BTU/yr}$  or .42 quads of primary energy.

The question of how much of this potential savings will be realized depends on large scale consumer acceptance of the heat pump as an alternative to gas, oil or resistance heat. This in turn depends on the incentives that the home buyer has to choose one system over another. The greatest inducement will probably be financial, especially in light of the present and projected fossil fuel rates. Several studies have been done which indicate that heat pumps offer lower operating costs than oil heat in most regions of the country and are quite close to those for gas heat in many regions. A total cost comparison made in 1972 by Westinghouse Electric using 1972 projections for fuel prices through 1985 indicated that heat pumps may have the lowest overall annual operating costs by around 1979-1980. In view of the fact that these predictions were made before the fall of 1973 jump in fuel prices, the breakeven point may be much earlier. Calculations using 1972 fuel cost rates indicated that heating costs for a heat pump were \$44 a year more in Milwaukee as compared to a gas furnace. In Chicago, the costs were comparable, and in the southern cities of Atlanta and Daytona nearly \$40 per year was saved by using a heat pump. From this it would seem that heat pumps have been cost effective only in the warmer climates of the country, but in the future, fuel costs are expected to increase more rapidly than electric rates so that heat pumps should come to be cost effective over wider regions of the country. Table G.2.4-4 summarizes a study done by General Electric based on heating requirements and fuel costs in twelve selected cities. It indicates that heatings costs for a heat pump were lower than those for an oil furnace in all of the cities and lower than with a gas furnace in seven cities. If natural gas prices are deregulated, it should have a profound effect on these figures. Another point is that it is becoming increasingly difficult to get natural gas in some parts of the country, for example in the northeast.

The coefficient of performance of heat pumps is not yet high enough to result in a net primary energy savings over gas and oil furnaces in all parts of the country, but because they are operated with electricity, they result in a switch to energy source fuels which can be used in a central power station. Projections indicate that greater percentages of electric power will be generated using coal and nuclear which could result in a large savings of oil and natural gas. Continued research and development will be necessary to increase the performance of heat pumps to the point where they result in a net savings in primary energy. Heat pumps also offer the possibility of using sources of low grade energy such as waste heat or solar energy to heat homes with greater efficiency than can now be realized with conventional heating systems.

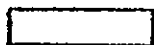
TABLE G.2.4-4. APPROXIMATE HOME HEATING COSTS AS OF 1974  
FALL [GE-74-1]

City	Gas <sup>(a)</sup>	Oil <sup>(b)</sup>	Heat Pump
Atlanta, Ga.	73.50	186.50	71.73
Boston, Mass.	341.57	420.00	381.12
Chicago, Ill.	245.20	495.00	240.71
Dallas, Texas	42.20	142.00	36.69
Kansas City, Mo.	90.69	352.00	100.53
Knoxville, Tenn.	104.02	256.00	78.39
Minneapolis, Minn.	261.02	587.00	340.17
Philadelphia, Pa.	220.20	360.00	196.56
Phoenix, Ariz.	29.29	71.50	23.46
San Diego, Calif.	16.86	37.70	18.28
Seattle, Wash.	190.51	267.00	61.57
Washington, D. C.	163.27	305.00	189.86

## Seasonal Conversion Efficiency

(a) Gas 50%

(b) Oil 45% &amp; oil at 36¢/gallon



Lower cost than gas



Lower cost than oil

Energy savings in addition to that projected in this example could be realized if a greater percentage of the new construction included the installation of electric heat pumps and if the COP of new units could be increased to a level where there were primary energy savings in all areas of the country. Installation of heat pumps in homes as replacements for oil furnaces could also lead to energy savings. If 10% of the homes presently heated with oil and gas were converted to heat pumps, 240,000 barrels of oil per day could be saved. [COPPS-75] If the 20 million homes presently heated with oil were converted to the heat pump, 2.7 million barrels per day would be saved or 1 billion barrels per year [GE-74].

### Technology

The advantages of using heat pumps for space conditioning have been known to engineers in the HVAC industry for some time, but technical problems have impeded their development and market acceptance until quite recently. The earlier models were in many cases merely standard air conditioning units which were reversed for heating purposes. Consequently, these units used standard air conditioner compressors that had not been designed for year round duty, and the reliability was poor; hence, dissatisfied owners, which resulted in poor market penetration. In the last few years, heat pump manufacturers have been able to overcome the technical problems mainly through redesign of the compressor so that the reliability is good enough that most manufacturers and some utilities offer up to 10 years assured service contracts at nominal cost to the owner. Research and development has continually aimed at increasing the coefficient of performance of heat pumps and manufacturers project a 50 to 100% increase in this measure of performance in the next 10 years. This would make a heat pump system considerably more energy efficient than fossil fuel burning furnaces. The increased reliability and efficiency has resulted in greatly increased consumer acceptance of heat pumps, and manufacturers project very high new home market penetration by 1985.

### Impacts

This action could lead to financial savings for the homeowner who installs a heat pump system as well as primary energy savings (at the power plant). The ease of implementing such an action would be closely linked with the financial benefits to be realized as well as the time period for this realization, i.e., the payback period.

A heat pump system costs from \$300 to \$500 more than a conventional furnace-air conditioner system (including installation) but in many cases would involve lower operating costs, depending on the local weather conditions and prevailing electricity and fuel costs. The energy savings to be realized would also depend on the geographic distribution of homes, as the efficiency is a function of the temperature difference between the outside and the conditioned space. Widespread acceptance of heat pumps will then depend to a large extent on consumer education to the concept of life cycle costing so that he is aware of the possible financial benefits. Government may become involved through consumer education, financial incentives and research and development of more efficient and reliable systems.

Projections of heat pump manufacturers have predicted that they will have the capital, manpower and materials necessary for the increased demand foreseen for heat pumps. There will be an increased demand for trained personnel to install and service heat pumps, but the major utilities and manufacturers are already setting up training programs. The demand for heat pumps should be monitored quite closely so that if demand has a tendency to increase to a level greater than can be supplied (because of widespread consumer education or government incentives or mandates which encourage heat pump installation) the manufacturers will have sufficient lead time to increase production.

Heat pumps do increase the first cost of a house slightly, so widespread installation by builders may lead to a depression of the new housing market if consumers are not educated with regard to the advantages and disadvantages of this type of space conditioning system. Another economic impact will be to increase demand for electricity so that the utilities will have to include this increased demand in their projections. Although if heat pumps are installed in lieu of electric resistance heat, the demand will decrease. The increased electricity demand during the winter may help to alleviate the summer peaking problem and result in lower utility prices or smaller increases for consumers. The effect of the move to electric heat on employment should be examined carefully. It may be that heating and air conditioning distributors cannot easily switch to heat pump installation or that local fuel distributors will be adversely affected.

Environmentally, the adoption of electric heating systems has the effect of moving the source of pollution to the central power source. Resistance heating results in greater air pollution because of its lower overall raw fuel efficiency, but the heat pump will result in lower overall emissions than oil or gas because of its greater efficiency and the better facilities for emission control at the central power plant.

Overall, the installation of heat pumps in lieu of resistance or fossil fuel heating units appears to be quite feasible from the standpoint of impacts. However, if a concerted effort to greatly increase the market penetration (as for example by government) is undertaken, the implications as to employment, the construction industry, manufacturers, etc. must be studied carefully so that the transition could be accomplished with the least amount of disruption possible.



### G.3. RESIDENTIAL/COMMERCIAL SUBSTITUTION ACTIONS

This section presents a more detailed explanation of the systems approach used in identifying the means for energy conservation by substitution for scarce energy resources which was outlined in Chapter 7. A specific action, solar heating and cooling, is used as an example to illustrate the broad-based analysis needed to accomplish a systems study.

#### G.3.1 CONSERVATION THROUGH SUBSTITUTION FOR SCARCE FUELS

As previously indicated in Chapter 7, the Residential/Commercial sector was divided into three sub-study groups. The objective of this sub-study analysis was to identify means for energy conservation by substitution for scarce energy resources.

In order to effectively deal with this topic, a working definition for 'scarce' must be determined. It can be theorized that any resource capable of being utilized for energy generation has a finite limitation and can, therefore, be classified as scarce. Scarcity, however, must be viewed within the framework of a specific time to be relevant. The sun can be cited as a representative example of a source which offers a theoretically unlimited source of energy within the context of current (time framework) knowledge and understanding of the sun/earth relationship. It can be argued, however, that the sun has a finite limitation and therefore, at some future time, will become a "scarce" resource. Within a relative time frame, coal may also be considered a "scarce" resource, although estimates of from 700 to 1500 years availability are projected for the U. S.

The sub-studies for the substitution study involved the following areas (see Figure G.3.1-1).

- Identify conservation actions

- Assess potential energy conservation of actions

- Identify barriers to implementation

- Identify incentives for implementation

- Assess impacts

Each of these areas is discussed in more detail below.

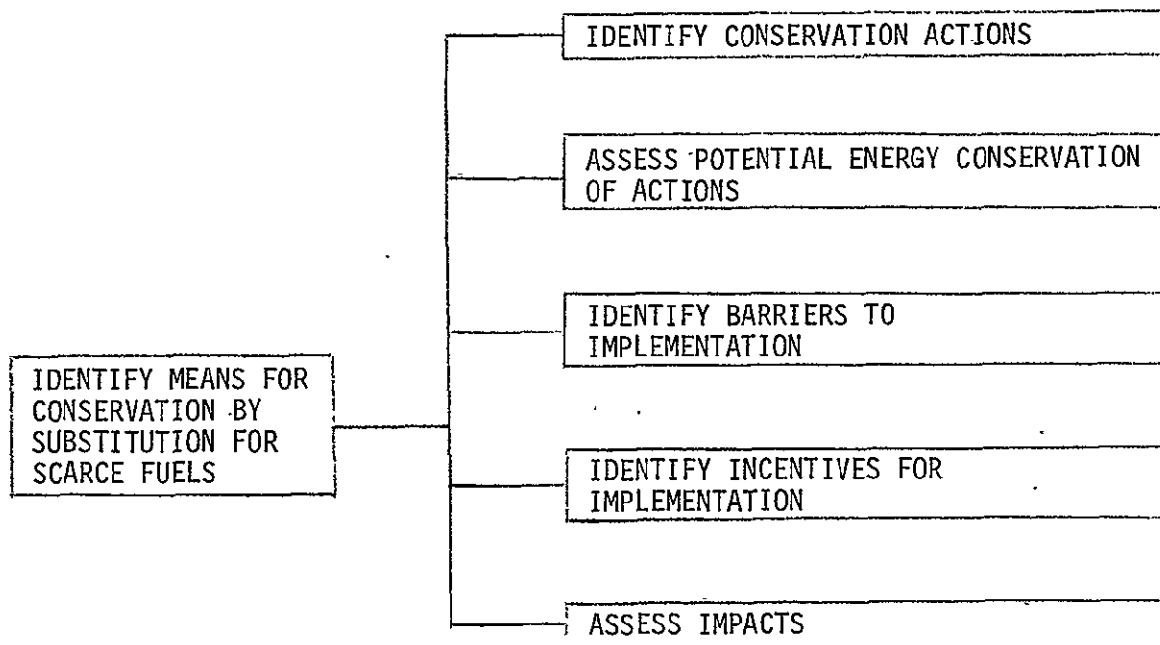


FIGURE G.3.1-1 SCHEMATIC OF "SUBSTITUTION" SUB-STUDY SYSTEMS APPROACH

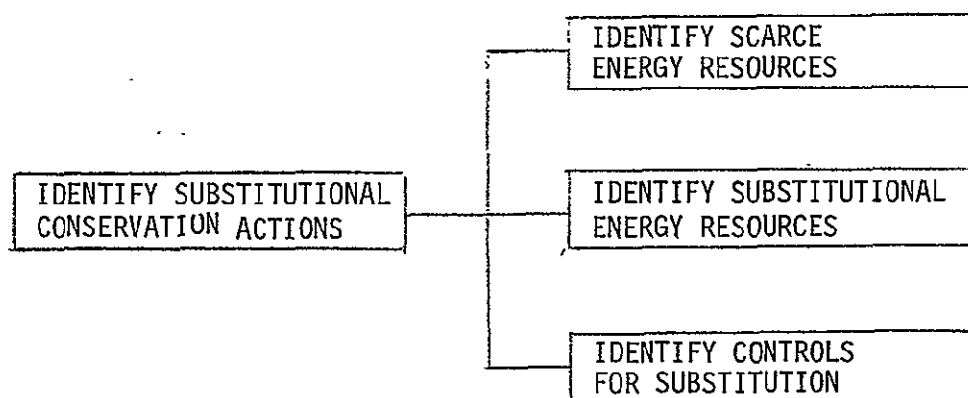


FIGURE G.3.1-2 METHOD FOR IDENTIFYING CONSERVATION ACTION

### Identify Substitutional Conservation Actions

In order to be able to identify those actions which will qualify as substitution conservation actions, three basic areas of information must be determined (see Figure G.3.1-2).

Scarce energy resources

Substitution energy resources

Controls for substitution

"Identifying scarce energy resources" itself can be considered a sub-study which would have the following requirements:

Identify present and projected levels of energy resource availability.

Develop end use profile, both by usage and source energy type.

The identification of those energies which are to be considered scarce must also acknowledge factors beyond resource availability. For instance, the effort of "Project Independence" to reduce oil imports could create a 'scarcity' of oil within the U. S. even before world oil reserves are depleted. Also, the time frame considered will be a vital factor in deciding if a particular energy resource is scarce. All non-renewable energy resources may be considered scarce if the time frame selected is sufficiently long.

Through a broad based literature search, current and projected levels of fuel availability as well as end use profits were identified. As a result of the analysis of these availability/demand profiles, the primary "scarce" resources for which substitutional sources should be sought were identified to be oil and gas.

The "identification of substitutional energy resources" appears to divide itself into three areas:

Identify types of substitutional energies

Investigate technological feasibility

Determine reserves or capacity

The types of substitutional energies should not be limited to the 'alternate' energies (such as solar, wind, geothermal, trash incineration), but must also include substituting such things as coal for natural gas or oil. In fact, any presently non-scarce energy resource should be studied as a possible substitution for any scarce energy resource. However, it

should be noted the technological feasibility (including economics) may be uncertain for a variety of reasons, including costs of other fuels, materials, manpower, etc., both now and certainly in the future. Often the potential reserves or ultimate capacity of the substitutional energy is uncertain due to technical unknowns (conversion efficiency) or ignorance of the basic resource (how much wind energy and where?).

This "identifying resources" phase of the analysis led to the identification of the myriad substitutional possibilities which included the following:

solar	wind
hydropower	bio-mass conversion
hydrogen	solid waste conversion
methane	geothermal
coal	

Potential energy to be derived from some of these sources is indicated in Table G.3.1-1.

Consideration was given to the technical feasibility of adopting the aforementioned sources directly to residential or commercial installations, i.e., using the source for local power generations as opposed to generating the power at a remote plant and distributing it. This possibility seems to be beyond near term capabilities for many potential substitutional sources due to costs, proximity of the end user relative to the power source location (as in the case of geothermal), pollution problems and lack of available technology.

To "identify the controls" (constraints and criteria) involved in substituting for scarce energy resources, two basic divisions seem to exist:

Technological controls;

Social controls.

Technological controls are those technical constraints and criteria operating on a particular substitution action. These technological controls would involve the 'engineering feasibility' of the action. The social controls would involve institutional (financial, political, legal) and sociological interactions associated with the substitutional actions. As was recently demonstrated with nuclear power, the social controls may veto a technically feasible action but they may also force an "uneconomic" proposal such as anti-pollution devices.

TABLE G.3.1-1. POTENTIAL OF SELECTED SUBSTITUTIONAL ENERGY RESOURCES  
IN THE U. S. [MEGASTAR - 74]

coal (Jan. 1, 1972)	$3.2 \times 10^6$ million tons
hydropower	126 GWe (all sites)
solar (entire U. S.)	4,500 Quads/year
- Arizona	1900 BTU/FT <sup>2</sup> --DAY
- New England	1100 BTU/FT <sup>2</sup> --DAY
wind	$10^{11}$ KWe*

\* [NSF/S.E.P. -- 72]

Engineering feasibility is a dependent variable based upon present technology, present research and development, future investment by government and industry, governmental policies, industrial interests, and the desire expressed by the public for a particular energy source. To some extent, these factors also reflect social controls.

As a result of an analysis of the previously mentioned potential substitutional sources, a list of conservation "actions" was generated (Table G.3.1-2). This list was then evaluated by examining specific elements that would be instrumental in determining the viability of selected substitutional conservation actions.

#### Assess Potential Energy Conservation of Actions

The assessment of the potential for energy conservation of a particular action involves several sub-studies (see Figure G.3.1-3):

- Identify potential energy savings (net energetics);

- Identify material requirements;

- Identify manpower requirements;

- Identify capital requirements;

- Identify time frame for implementation.

It should be noted that some of the above areas will involve 'best guess' type analyses. Also, in identifying a particular conservation action, much of the information needed will be generated for assessment of that action.

Table G.3.1-3 reflects a matrix analysis of all actions identified within the scope of this study. This table displays the initial assessment concerning requirements and impacts of each action.

#### Identify Barriers and Incentives to Implementation

The identification of barriers and incentives to implementation of a substitution energy conservation action is an ongoing problem throughout all phases of the entire study. It should also be noted that barriers and incentives can be generated internationally, nationally, and locally, regardless of the particular substitution action taken. Also, any conservation action can induce its own incentives and barriers depending on the method of implementation.

TABLE G.3.1-2. LIST OF SUBSTITUTIONAL CONSERVATION ACTIONS IN THE RESIDENTIAL/COMMERCIAL SECTOR\*

Using solar insolation for space heating and cooling of buildings

Using solar insolation to generate electricity

Using wind energy to generate electricity

Using trash, garbage, or sewage as a fuel

Using hydro-power at the local level

Using electricity generated by a non-scarce fuel to replace burning oil or gas

Using coal to heat and cool instead of oil or gas

Using hydrogen or methane in place of natural gas

\* All actions are assumed to be 'LOCAL': Either at the user location or close-by; i.e., The District Concept of energy usage

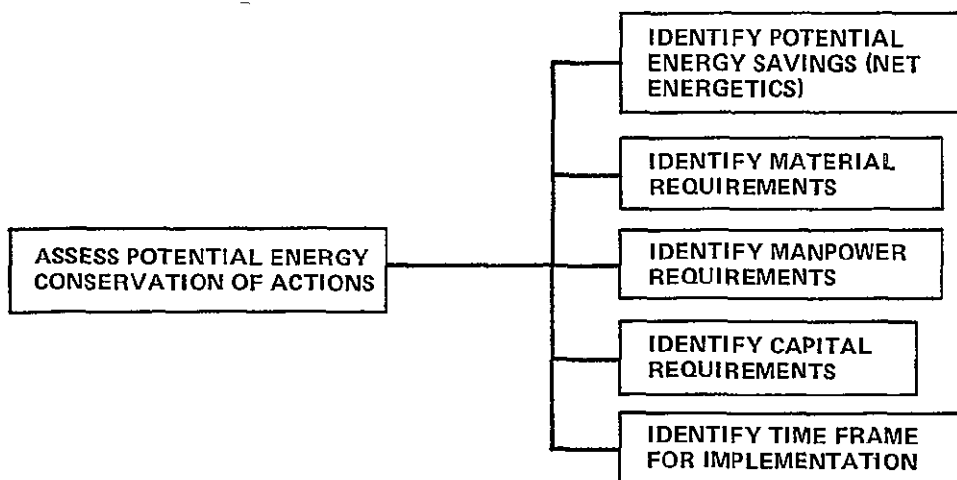


FIGURE G.3.1-3

METHOD FOR ASSESSING POTENTIAL OF CONSERVATION ACTION

TABLE G.3.1-3 CONSERVATION ACTION EVALUATION MATRIX

CONSERVATION ACTION	POTENTIAL SAVINGS	EASE OF IMPLEMENTATION	AVAILABILITY			IMPACTS				OVERALL FEASIBILITY	COMMENT
			CAPITAL	MANPOWER	MATERIALS	SOCIAL	POLITICAL	ECONOMIC	ENVIRONMENTAL		
Using hydropower at the local level	+L	-L	-L	-L	+L	+L		-L	-L	-M	<ul style="list-style-type: none"> <li>Installing <math>2 \times 10^5</math> residential units saves 0.06 Quads/yr. (assumed farming families are total market with 10% participation)</li> </ul>
Using hydrogen in place of natural gas	+H	-M	-H	-L	-L	-L	-M	-M	-L	-L	<ul style="list-style-type: none"> <li>Assumed 7% appliance conversion/yr. and replaced 500 billion SCF nat. gas/yr.</li> <li>Change-over schedule:               <ul style="list-style-type: none"> <li>-1985: .5 Quad hydrogen in place</li> <li>-1990: 3 Quad</li> <li>-2000: 8 Quad</li> </ul> </li> </ul>
Using electricity generated by a non-scarce fuel (coal) to replace direct use of petroleum and natural gas	+M	+M	+M	+L	+M	-L	-L	-M	-H	+L	<ul style="list-style-type: none"> <li>All new and replacement building not allowed to use oil or gas</li> <li>Savings in 1985 LP.I.-741               <ul style="list-style-type: none"> <li>-oil: 0.11 Quad/yr.</li> <li>-N.G.: 1.14 Quad/yr.</li> <li>-coal: 3.76 Quad/yr. additional consumed</li> </ul> </li> </ul>
Using coal directly to heat and cool instead of oil and gas	+H	-H	-H	-H	-H	-H	-H	-H	-H	-H	<ul style="list-style-type: none"> <li>Coal would become over 50% of res./comm. direct energy input</li> <li>Enormous conversion and retro-fit operation necessary</li> <li>Distribution system would have to be set-up</li> </ul>

"+" = favorable or positive  
 "-" = unfavorable or negative  
 "H" = high  
 "M" = medium  
 "L" = low  
 " " = no effect



TABLE G.3.1-3 CONSERVATION ACTION EVALUATION MATRIX (Cont.)

CONSERVATION ACTION	POTENTIAL SAVINGS	EASE OF IMPLEMENTATION	AVAILABILITY			IMPACTS				OVERALL FEASIBILITY	COMMENT
			CAPITAL	MANPOWER	MATERIALS	SOCIAL	POLITICAL	ECONOMIC	ENVIRONMENTAL		
Use solar energy for space heating and cooling and hot water heating	+M	+H	+H	+H	+H	+L	+M	+M	+L	+H	<ul style="list-style-type: none"> <li>Minor implementation period in 1985 to 1995 time frame</li> <li>Savings about 2-6 quads/yr by 2000</li> <li>Assumed government continues backing</li> <li>Regional implementation is uneven.</li> </ul>
Use solar insolation to generate electricity	+L	+L	-M	+H	+M	+L	+M	+M	+L	+M	<ul style="list-style-type: none"> <li>Time frame: beyond 1995</li> <li>Severe cost/KW barrier at present; uncertain future costs</li> </ul>
Use wind energy to generate electricity	+L	+L	+L	+H	+H	+L	+M	+M	+M	+M	<ul style="list-style-type: none"> <li>Large long range potential</li> <li>Storage problem</li> </ul>
Use trash, garbage or biomass as fuel	+H	+M	+M	+H	+H	+L	+H	+H	+M	+H	<ul style="list-style-type: none"> <li>Potential: <ul style="list-style-type: none"> <li>- 1980: 0.007 quad/yr.</li> <li>- 2000: 10 quad/yr. (max.)</li> </ul> </li> <li>implementation).</li> <li>Biomass is long range, trash is short to mid-range for implementation.</li> </ul>

"+" = favorable or positive  
 "-" = unfavorable or negative  
 "H" = high  
 "M" = medium  
 "L" = low  
 "" = no effect

### Assess Impacts

The term impact as used here is in the broadest possible sense. A substitution action will be evaluated as to its impacts not only on the material, labor, and capital markets, but with respect to its effect on life-style, institutional structure, environment, and any other area that may be affected. A general approach to this study of impacts might be by studying:

The users

The producers

The regulators

Overall, assessing the impacts becomes a 'brain-storming' activity in order to relate as many of the impacts as possible.

### G.3.2 EXAMPLE OF SUBSTITUTIONAL IMPACT ANALYSIS

Within the framework of this study, it was decided to assess the potential impact from a specific action which would serve as a test case for future assessment activities. It was felt that such an exercise would be useful in formulating an analysis technique that could be applied in the assessment of any alternate action deemed worthy of analysis. Discussions have revealed that significant impacts could result from the institution of solar systems as a substitutional source in lieu of currently available heating and cooling systems in the residential/commercial sector. The following analysis reflects an in-depth study related to such an action. Reasons for choosing this action included the following factors.

The potential conservation energy savings are reasonably high.

The Federal Government has indicated interest in this action.

Public enthusiasm has been generated for this action.

Industry appears interested in entering the solar field.

### Current Status

Efforts to use solar energy for heating and cooling have met with limited success to date. The basic technology is available and the principles have been demonstrated; in fact, several working systems have been built in the United States.

Figure G.3.2-1 is a schematic diagram of a specific heating and cooling system. The three basic types of solar systems are those which permit hot water heating, hot water and space heating, and hot water, space heating and cooling. Common characteristics of most current systems include:

Flat plate collectors;

An energy storage system;

An auxiliary energy source to supplement the solar capability.

Since the collection and storage required to take care of the maximum possible heating/cooling load conditions is far too expensive to be practical, a supplemental energy source must be provided. However, the supplemental energy source must be capable of supplying the full heating or cooling requirements of the building at the time when the demand is the greatest. The thermal energy available from the collector or storage units can be used directly for space and water heating or to operate a heat actuated cooling unit. As with space heating and cooling with conventional energy sources, various pumps, controls and facilities for circulating air from the heating and cooling units to the conditioned space are required.

Presently, space heating and hot water heating are the closest to being economically viable. With rising fuel costs and more attentive consumers, space and hot water systems should be competitive within three to four years. The technology for space cooling systems is not as well developed and lags heating system development by approximately five years.

#### Consumer Status

The public appears enthusiastic about the introduction of solar heating and cooling. Several individuals have, at their own expense, installed heating and hot water systems on their homes. Popular literature has reflected this public interest with many articles detailing "How-To" techniques as well as reporting the latest developments in solar research. However, the high initial cost has been the restraining factor against wide-spread implementation.

#### Industry Status

The technology for solar space heating exists now and manufacturers are beginning to make subsystems and systems available, but current prices are high. The application of this technology to user needs must be demonstrated convincingly, production increased, and prices reduced appreciably before a sufficient market can be developed. Also, standards must be set and methods developed to assure the buying public that the standards are being met. The recent founding of the Solar Energy Industry Association (SEIA) illustrates the ready-and-willing attitude of industry to enter the solar field.

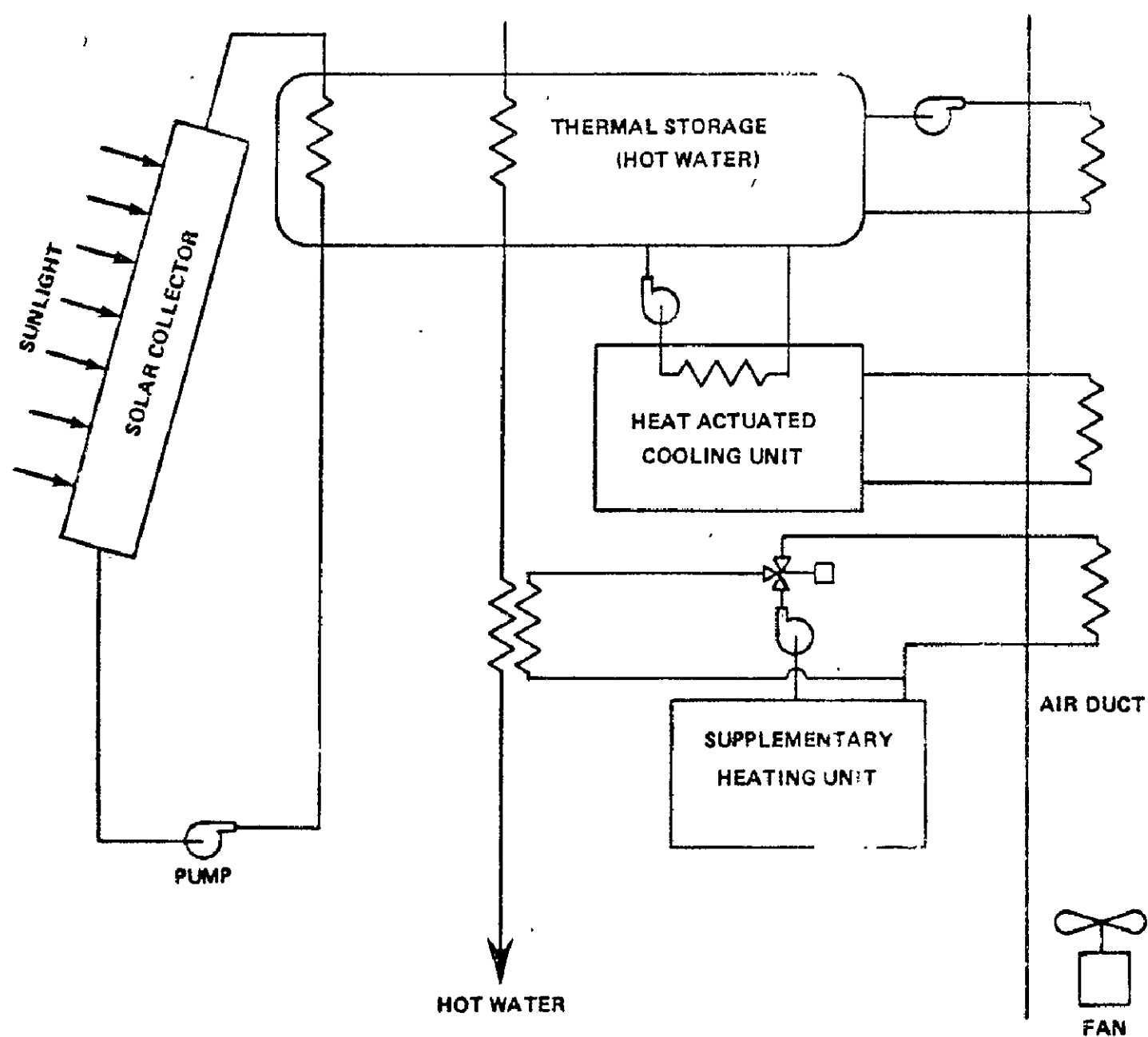


FIGURE G.3.2-1. COMBINED SOLAR SPACE HEATING AND COOLING SYSTEM WITH HOT WATER STORAGE [TERRASTAR-73]

### Government Status

The Federal Government is presently undertaking a national plan for solar heating and cooling. ERDA is acting as the lead federal agency in cooperation with other participating agencies. NASA has the responsibility for management and development of the solar heating and cooling systems which are to be installed nation-wide under the plan. The laws passed by the 93rd congress dealing with this program are:

Solar Heating and Cooling Demonstration Act of 1974, P.L. 93-409, September 3, 1974;

Energy Reorganization Act of 1974, P.L. 94-438, October 11, 1974;

Solar Energy Research, Development, and Demonstration Act of 1974, P.L. 93-473, October 26, 1974;

Federal Non-nuclear Energy Research and Development Act of 1974, P.L. 93-577, December 31, 1974.

The overall goal of the plan is to stimulate the creation of a viable industrial and commercial capability for producing and distributing solar heating and cooling systems, thereby reducing the demand on present fuel supplies through widespread use in residential and commercial buildings and applications. The plan calls for the demonstration of solar heating by the end of Fiscal Year 1977 and the demonstration of combined solar heating and cooling by the end of Fiscal Year 1979. Also included are supporting research and development, collection and dissemination of information, and suggested Government policy measures to accelerate implementation and market development. [ERDA 23-75]

The National Plan for Solar Heating and Cooling includes three major elements:

Demonstrations for both commercial and residential applications, initially utilizing available systems;

Development in support of the demonstrations, initially utilizing available subsystems and components;

Research and development to advance solar heating and cooling technology essential to the timely progress of the demonstrations and the eventual large scale applications.

On the state level, governmental emphasis has been primarily on the providing of incentives for installing solar equipment, with very little solar research or development being instigated by the states. Indiana recently instituted a tax exemption on installed solar systems, and many other states have pending legislation along this same line. Also, several states are investigating the possibilities of demonstrating solar heating and cooling by having systems installed on newly constructed state buildings.

## Requirements

The requirements of solar systems for capital, manpower, and materials depend on both the extent and rate of implementation or installation. For example, with the installation of one million systems within the next two years, the requirements might not be able to be met. However, if the goal is to install these systems over a ten year span, then the availability of capital, manpower, and materials is more likely.

Several studies [PI-74, Ford-74, Terrastar-73] have projected the expansion of solar development. Figure G.3.2-2 shows these projections of solar energy in service from 1985 to 2000. The requirements for the Project Independence projections are shown by Table G.3.2-1 for space heating and hot water combined, and by Table G.3.2-2 for hot water heating alone.

The Ford Foundation [FORD-74] projects solar utilization in its "Technical Fix Base" scenario. Table G.3.2-3 lists the requirements for the Ford projection by five year increments. Table G.3.2-4 standardizes these requirements by stating them per million square feet of installed collector.

ERDA has projected the number of annual solar installations and the fuel savings by year from 1976 to 1985. Table G.3.2-5 shows these solar starts, including commercial retrofits. The Westinghouse Phase 0 Solar Study [Westinghouse-74] projects the percent of new construction that would be cost competitive using solar-assisted space heating and cooling, and this is shown in Figure G.3.2-3.

Overall, the material, manpower, and capital requirements do not seem excessive in any of the projections. The availability of these requirements should not be a bottle-neck to the development and expansion of solar heating and cooling systems.

## Barriers to Implementation

The barriers to implementation of solar systems may exist from the manufacturer down to the consumer. These barriers may be raised by governments, institutions, special interest groups, or by the consumer himself. Presently, the identification of barriers is a task taken on by the manufacturer of the particular item when considering marketability. However, the identification of barriers should not stop with just getting the item marketed. Any future-time barriers should be addressed before they are met. A partial listing of barriers, incentives to overcome these barriers, and specific actions are given in Table G.3.2-6.

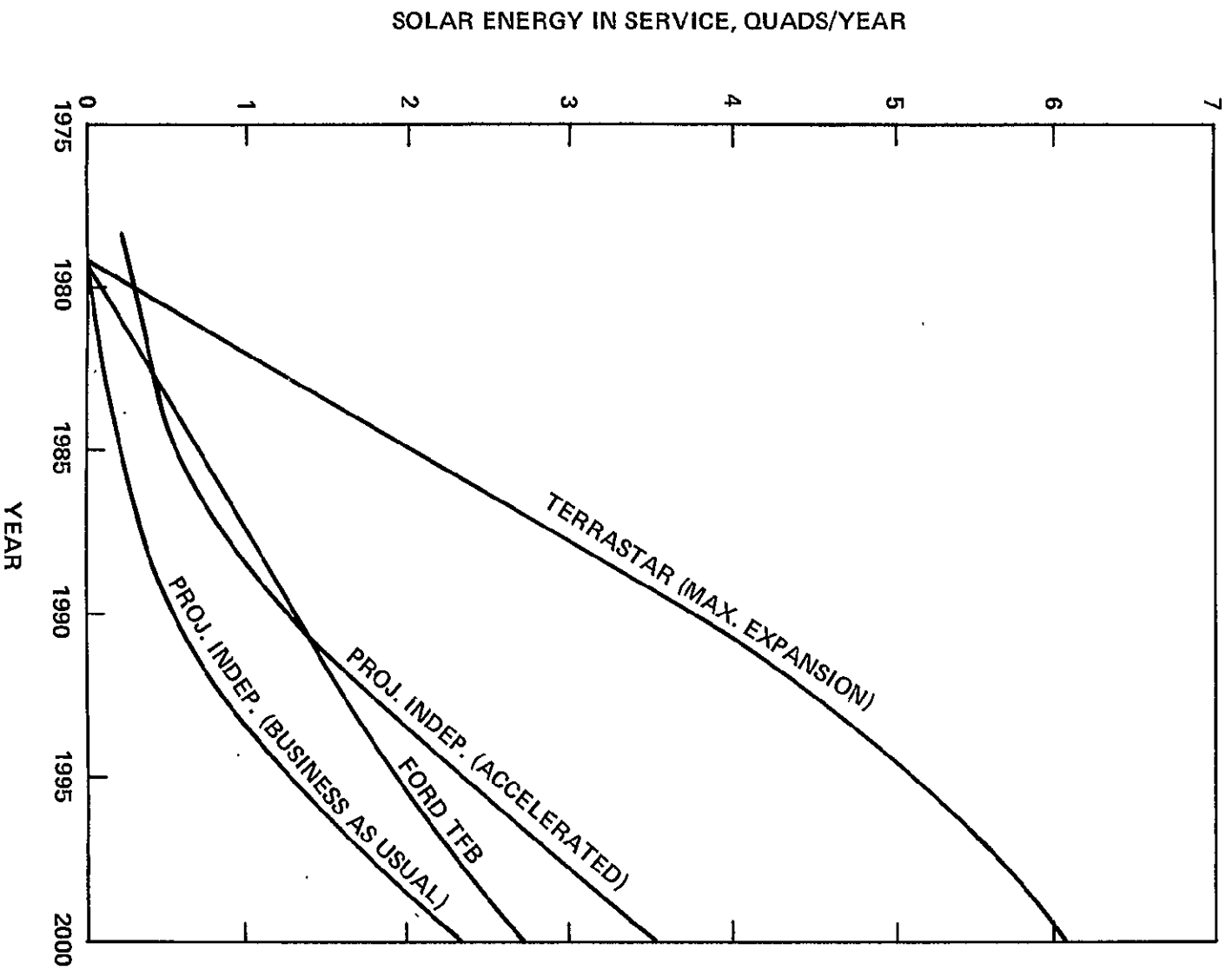


FIGURE G.3.2-2. COMPARISON OF SOLAR DEVELOPMENT: FORD TFB PATH REQUIREMENT, TERRASTAR ESTIMATE, PROJECT INDEPENDENCE

C. 7

TABLE G.3.2-1 SOLAR SPACE HEATING AND HOT WATER FOR SINGLE FAMILY AND  
SMALL COMMERCIAL BUILDINGS [PI. DRAFT-74]<sup>1</sup>

	UTILIZATION (10 <sup>15</sup> BTU/yr)	ANNUAL INSTALLATION OF NEW UNITS (Includes Hot Water Only Systems)		CAPITAL REQUIREMENTS (10 <sup>8</sup> \$/yr) (Plant + Consumer)	MATERIAL REQUIREMENTS (10 <sup>3</sup> TONS/YR)			MANPOWER (10 <sup>3</sup> MAN-YEARS) PER YEAR
		SINGLE FAMILY	SMALL COMM.		Aluminum	Glass	Steel	
1980 <sup>2</sup>	.280 (.012)	117,000 ( 58,000)	72,000 (13,600)	53 (17.0)	605 (146.9)	826 (199.9)	1339 ( 346.6)	67 (18)
1985	.550 (.280)	205,000 (102,500)	126,000 ( 62,500)	89 (45)	1064 ( 532)	1452 ( 726)	2333 (1166)	116 ( 58)
1990	1.490 ( .550)	205,000 (205,000)	126,000 (126,000)	89 (89.3)	1064 (1064)	1452 (1452)	2333 (2333)	116 (116)
1995	2.4 (1.3)	205,000 (205,000)	126,000 (126,000)	89 (89.3)	1064 (1064)	1452 (1452)	2333 (2333)	116 (116)
2000	3.5 (2.3)	205,000 (205,000)	126,000 (126,000)	89 (89.3)	1064 (1064)	1452 (1452)	2333 (2333)	116 (116)

<sup>1</sup> Oil at \$11/bbl

<sup>2</sup> Numbers shown refer to "Accelerated Development" with "Business As Usual" numbers in parentheses.



TABLE G.3.2-2. SOLAR HOT WATER HEATING FOR SINGLE FAMILY AND  
SMALL COMMERCIAL BUILDING WITH NO ACCELERATED  
PROGRAM<sup>a</sup> [P.I DRAFT-74]

YEAR	DIRECT ENERGY SAVING (10 <sup>15</sup> BTU)		ANNUAL INSTALLATION OF NEW UNIT		MATERIAL REQUIREMENTS (TON/YR)			MANPOWER REQUIREMENTS (MAN-YRS/YR)	CAPITAL REQUIREMENTS (10 <sup>8</sup> \$/yr)
	<u>SING.FAM</u>	<u>SM.COMM.</u>	<u>SING.FAM.</u>	<u>SM.COMM.</u>	<u>ALUMINUM</u>	<u>GLASS</u>	<u>STEEL</u>		
1978			6,850	2100					
1980	.00036	.00308	13,700	8400	17,810	22,640	14,400	3,334	3.84
1990	.070	.172	137,000	84,000	290,280	422,600	241,000	30,430	21.2

a. Oil at \$11/bbl

TABLE G.3.2-5 ANNUAL SOLAR STARTS AND FUEL SAVINGS <sup>3</sup> [ERDA 23-75]

		<u>1976</u>	<u>1977</u>	<u>1978</u>	<u>1979</u>	<u>1980</u>	<u>1981</u>	<u>1982</u>	<u>1983</u>	<u>1984</u>	<u>1985</u>
RESIDENTIAL	Annual Starts <sup>1</sup>	0.01	0.03	0.1	0.5	2	5	7	10	15	15
	Annual Fuel Savings <sup>2</sup>	3.2	12.8	44.9	205.4	847.4	2452.4	4699.4	7909.4	12,724.4	17,539.4
COMMERCIAL	Annual Starts <sup>1</sup>	0.1	0.3	1	5	20	50	70	100	150	200
	Annual Fuel Savings <sup>2</sup>	2.4	9.6	33.7	154.2	636.2	1841.2	3528.2	5938.2	9553.2	14,373
COMMERCIAL	Annual Retrofits <sup>1</sup>	0.1	0.6	1	2	3	2	2	1	1	0.5
	Annual Fuel Savings <sup>2</sup>	32.1	224.1	545.7	1187.7	2150.7	2,792.7	3434.7	3755.7	4076.7	4237.2
RES/COMM	Total Annual Fuel Savings <sup>2</sup>	40	250	620	1550	3630	7090	11,660	17,600	26,350	36,150

1. In thousands of units.

2. In thousands of barrels of oil equivalent energy saved per year.

3. Assuming 60% solar substitution, with 1500 FT<sup>2</sup>/housing unit and 150,000 BTU/FT<sup>2</sup>-yr for residential, and with 15,000 FT<sup>2</sup>/comm. unit and 200,000 BTU/FT<sup>2</sup>-yr for commercial.

TABLE G.3.2-3 SOLAR HOME HEATING AND COOLING REQUIREMENT  
FOR FORD TECHNICAL FIX BASE [MEGASTAR-74]

	<u>1975-80</u>	<u>1980-85</u>	<u>1985-90</u>	<u>1990-95</u>	<u>1995-2000</u>
Solar Quads/year	0.1	0.7	1.4	2.1	2.7
Ft <sup>2</sup> Collector (billions)	0.1	1.2	2.6	3.7	4.8
Aluminum (thousand tons)	32	240	300	250	250
Glass (million tons)	0.1	1.1	1.4	1.1	1.1
Insulation (thousand tons)	22	160	200	170	170
Steel (million tons)	0.1	1.1	1.4	1.1	1.1
CPVC Pipe (thousand tons)	15	110	130	110	110
Cost (billions)	2	12	15	12	12
Engineering Manpower	200	1,800	3,700	5,300	6,900
Other Manpower	2,500	20,000	43,000	61,000	79,000

TABLE G.3.2-4 SOLAR ENERGY SYSTEM UNIT REQUIREMENTS PER  
MILLION SQUARE FEET OF FLAT PLATE COLLECTOR  
[MEGASTAR-74]

<u>Item</u>	<u>Quantity</u>
Aluminum	400 Tons
Glass	1,000 Tons
Insulation	150 Tons
Steel	1,000 Tons*
CPVC Pipe	100 Tons
Cost	\$11 Million
Manufacturing Manpower	60,000 Manhours
Installation Manpower	120,000 Manhours
Useful Energy Generated Per Year	.00056 Quads

\*Fiberglass tanks could also be used; price is approximately the same.

TABLE G-3.2-6 SUMMARY OF INCENTIVES AND ACTION OPTIONS [ERDA 23-75]

<u>Barriers to Implementation</u>	<u>Types of Incentives</u>	<u>Action Party/Agency</u>	<u>Specific Action Steps</u>	<u>Parties Affected</u>
1. High first costs are a disincentive to the consumer	* Income tax deduction	Federal and State Governments	Develop effective tax deduction formula	Greater incentive for high income groups than low
	* Income tax credit	Federal and State Governments	Allow a tax credit of some % of installed costs or mortgage payments	Home owner, all income groups
	* Direct subsidy	Federal and State Governments	Direct assistance in the purchase of solar equipment	General public
	* Assure that mortgage	Federal Government	Influence the Federal Home Loan Bank Board, FNMA, and GNMA	Financial institutions; homebuyers
	* Guaranteed and insured loans	Federal Government	Raise the limit on FHA-insured mortgages to cover solar systems	Financial institutions, homebuyers
	* Low interest Federal borrowing	Federal Government	Provision of low-interest loans	Homebuyers
2. Solar systems make a home more expensive and perhaps burden to sell	* Similar to those under 1. for the purchase of a solar equipped house	Federal and State Governments	As above	Homebuyers and sellers
3. It may be difficult and/or expensive to insure a solar equipped building	* Government insurance	Federal Government	Legislation to provide government insurance	Financial community, Homebuyers, Insurance Ind.
4. If construction materials purchased by builders are taxed, the cost of the solar system to the consumer will be increased	* Sales tax exemption or reimbursement for materials used in solar system installation	State and local governments	Change in tax law	Construction Ind. Homeowner
5. The solar system increases the price of a home and hence the property taxes	* Tax exemption	State and local governments	Develop provisions which are fair and equitable	Homebuyers, owners, and sellers
6. Solar systems in commercial buildings may yield an unfavorable rate of return	* Investment tax credit	Federal and State Governments	Extension of the investment tax credit to the cost of solar installations Work out a suitable formula	Investors
	* Accelerated depreciation	Federal Government		
7. The potential manufacturers may be skeptical about entering the business due to high initial production costs.	* Accelerated depreciation of capital equipment	Federal Government	Tax ruling	Manufacturers and indirectly consumers
8. Insufficient R&D	* Government grants and contracts	Federal and State Governments	Increase government R&D funds	Research community manufacturers

ORIGINAL PAGE IS  
OF POOR QUALITY

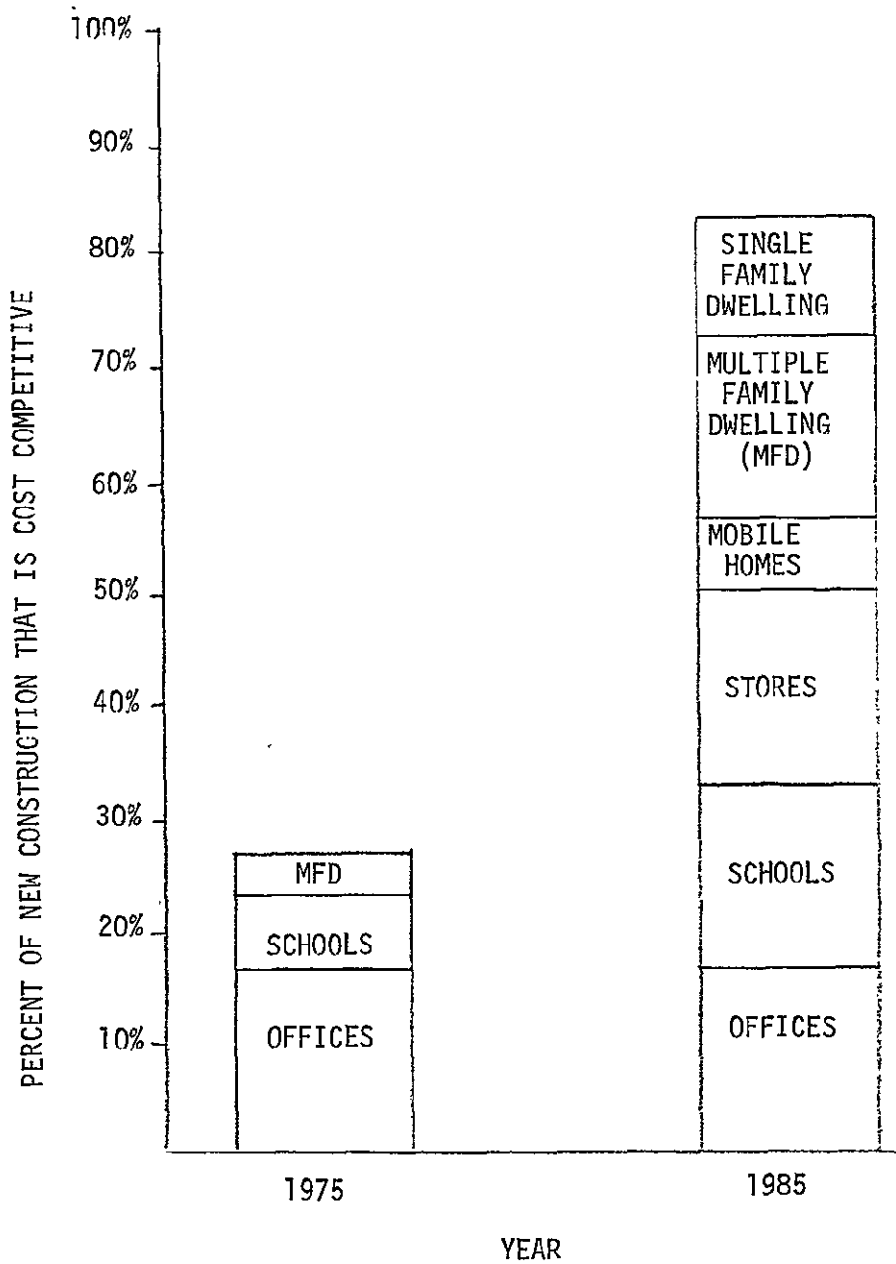


FIGURE G.3.2-3. TRENDS IN SOLAR-ASSISTED SPACE HEATING AND COOLING SYSTEMS COST-EFFECTIVENESS [Westinghouse-74]

The use of incentives to overcome barriers is probably the most popular method being tried today. Through the provision of incentives, the currently slow trend toward solar can be accelerated so as to achieve a favorable economic climate. Among the possible ways to achieve such an accelerated growth of the solar energy industry are the following alternatives:

- Income tax credits for solar systems;
- Sales tax exemptions on solar equipment purchases;
- Increase mortgage money availability and guarantee and insure loans for solar systems;
- Permit faster tax depreciation on solar systems;
- Permit fossil fuel prices to find natural supply/demand levels on the open market;
- Provide accurate climatic data for solar systems design;
- Adjust property taxes downward by the amount of solar equipment purchased to encourage use of solar energy systems;
- Remove preferential rate structures that encourage industrial and residential consumers to consume more energy.

While the aforementioned alternatives have a monetary value, the benefits exceed the costs in terms of fossil fuel savings, pollution reduction and improved balance of payments.

### Impacts

The implementation of solar energy systems to conserve scarce resources implies broad based repercussions in a number of societal areas. Increasing awareness of the many social, political, economic, and environmental repercussions, as well as other consequences resulting from such technology implementation, dictates the necessity to investigate the potential impacts from such an action. Impact analysis also permits an introspective examination of many latent factors that can have effects in such areas as product design, determination of potential market areas and distribution strategies which may yield crucial data as to the commercial feasibility of instituting an action.

This section, therefore, attempts to identify and discuss some of the potential impacts resulting from the implementation of solar energy systems to provide heating and cooling for the residential and commercial sectors.

### Environmental Impacts

In order to assess the effect of solar energy utilization as a substitutional resource, it is necessary to determine the total energy inputs versus energy outputs (net energetics) required to produce the collector system. The result of such a net energetics study based on the use of either steel, copper, or aluminum for the collector medium with a 1/4 inch glass cover and a 22 gauge steel sheet metal pan as the container for the components is shown in Table G.3.2-7. This study indicates the principal energy consumer to be the collector plate with steel reflecting the lowest cost. While copper and aluminum reflect the same energy cost, copper requires approximately one half the thickness of aluminum. The copper collector, however, is twice the weight and four times more expensive on a per pound basis than aluminum. Copper, on the other hand, possesses superior corrosion resistance which may make it more competitive on a life-cycle cost basis. Another impinging factor is that bauxite availability for aluminum production is almost totally reliant on imports while copper is almost totally domestically produced.

Table G.3.2-8 reflects the total collector energy costs based on the use of the previously mentioned materials. Based on the assumption that one square foot of collector will result in a reduced fossil fuel usage of 500 BTU/day, the energy investment associated with the steel collector will be repaid in 183 days (.5 years), while the copper and aluminum collector will return their initial energy investment in 254 days (.7 years). These payback periods are exclusive of thermal insulation gasket materials, and surface coatings, the inclusion of which would increase the payback period slightly.

Table G.3.2-9 reflects the impact of solar energy systems production upon the manufacturing industry. It can be seen that the most significant impact is created by the glass requirement which, at the production level of 500 million square feet per year, requires 41% of the 1972 consumption level. For a similar production level, copper creates the next greatest impact, requiring 13% of the corresponding 1972 production level followed by aluminum at 5%. Table G.3.2-9 also indicates a significant factor with respect to aluminum, i.e. the U. S. is almost completely dependent upon imports while copper is least dependent upon imports.

An "energy efficacy" net energetics analysis which compares the ratio of the energy contribution of a particular system to its energy cost over an assumed lifecycle period is reflected in Table G.3.2-10. Significantly, solar systems have the highest efficacy level of any system.

TABLE G.3.2-7 COLLECTOR COMPONENT ENERGY COSTS [TRW-74]

Material	Total Thickness (in)	Weight (lbs/ft <sup>2</sup> )	Energy Cost (Btu/lb)	Energy Cost Per Unit Collector Area (Btu/ft <sup>2</sup> )
<u>Covers &amp; Pan</u>				
Float Glass	0.25	3.3	$5 \times 10^3$	$16.5 \times 10^3$
Steel	0.0312	1.25	$20 \times 10^3$	$25.0 \times 10^3$
<u>Collector Plates</u>				
Steel	0.0624	2.50	$20 \times 10^3$	$50.0 \times 10^3$
Copper	0.0365	1.68	$51 \times 10^3$	$85.6 \times 10^3$
Aluminum	0.060	0.85	$100 \times 10^3$	$85.0 \times 10^3$

TABLE G.3.2-8 TOTAL COLLECTOR ENERGY COSTS [TRW-74]

Material	Energy Cost Per Unit Collector Area (Btu/ft <sup>2</sup> )	Payback Period* (Years)
Steel	$91.5 \times 10^3$	0.5
Copper	$127 \times 10^3$	0.7
Aluminum	$127 \times 10^3$	0.7

\*Assumes an average of 500 Btu/day of energy collected and utilized in the reduction of fossil fuel consumption.



TABLE G. 3.2-9 COLLECTOR MATERIALS REQUIREMENTS [TRW-74]

Material	1972 U. S Consumption (Million Tons)	Percent of Material Imported in 1972	50 Million Sq Ft./Year		500 Million Sq Ft./Year	
			Million Tons	Percent of 1972 Consumption	Million Tons	Percent of 1972 Consumption
<u>Cover and Pan</u>						
Float Glass	2.05	--	0.083	4.1	0.83	41
Steel	133	28	0.032	0.025	0.32	0.25
<u>Collector Plates</u>						
Steel	133	28	0.063	0.045	0.63	0.45
Copper	2.4	18	0.042	1.8	0.42	18
Aluminum	4.1	96	0.022	0.5	0.22	5

TABLE G.3.2-10 ENERGY EFFICACY COEFFICIENT FOR  
CONVENTIONAL AND SOLAR ENERGY SYSTEMS [TRW-74]

<u>SYSTEM</u>	<u>EFFICACY</u> <sup>*</sup>	<u>COMMENT</u> <sup>**</sup>
Coal mining	42	Excludes energy required for delivery to final demand
Petroleum refining	4.8	Excludes energy required for delivery to final demand
Gas utilities	5.9	
Nuclear fission reactors (LWR)	<32	Based entirely upon energy consumed by gaseous diffusion isotopic enrichment of fuel
Energy plantations	< 3	Electric output. American Southwest. Assumes three crops per year, field drying, and combustion to generate electricity
Ocean thermal gradients	<15	Electric output. Considers only energy input into material (aluminum) for boiler, condenser, and cool water intake conduit.
Photovoltaic system (large satellite)	< 6	Electric output. Published projections revised to account for indirect energy inputs into materials.
Photovoltaic system (large terrestrial)	<27	Electric output. Considers only total energy input to aluminum support structure for solar cell array.
Thermal system (large plant)	<55	Electric output. Considers only total energy input to aluminum support structure (which may form part of collector) and double glazed glass cover.
Thermal system (small plant, on buildings)	<56	Heat output. Considers only total energy input to copper rooftop collector and double glazed glass cover.

\* Thirty-year installation lifetimes are assumed.

\*\* Consideration of additional energy inputs necessarily reduces the energy efficacy coefficient.

### Land Use Modification

Future land use patterns will be changed somewhat as a result of widespread use of solar collectors. The retrofit market will be limited depending upon past land use patterns which defined orientation, roof type, tree locations, and general exposure to the sun. Geographic locations will present varying opportunities for retrofit. Areas of the country where most houses are of one-story construction, mostly oriented north-south with wide lots and few trees (such as Phoenix, Arizona), would present greater opportunities for retrofit than an area where housing is characterized by multi-story, multi-family units on narrow lots with a high degree of shading and random house orientation (such as Boston, Massachusetts).

New construction employing solar systems will require considerable consideration for orientation in order to maximize solar insolation. A general orientation of the long axis of buildings in the east-west direction will be common for buildings using roof-top collectors. Such orientation requirements will alter the relationship of buildings to streets in communities laid out on the typical grid pattern. The esthetic effects and resultant impacts on potential buyers may result in constraints to market penetration.

Consideration must also be given to adverse effects resulting from the proximity of single-story buildings to multi-story buildings with respect to sun exposure where roof-top solar collectors are employed. Permits for new construction will have to be evaluated to consider the possible effect a proposed building might have on adjacent buildings as a result of shadow patterns cast from the sun.

Building sites that are not conducive to the utilization of solar systems (shaded sites, sloping topography that does not permit proper orientation) may be refused permits for construction by city ordinances and building inspectors. Concepts of landscape design which encourage a decreased use of trees to beautify surroundings and to shade buildings will most likely result from the implementation of solar systems.

### Architectural Impact

The acceptance of solar systems will be largely dependent upon the integration of solar components into the total design of the building. This will present design challenges to the architectural profession and will require much greater attention to those design elements affected by the solar system, e.g. roof and wall surfaces, roof slope, physical appearance, orientation relative to the sun, collection/distribution system's design, materials' use, as well as consideration for

a total design that is conservation oriented. The requirement that architects be familiar with such design elements may require a need for continuing education programs to expose practicing professionals to the design ramifications associated with solar systems technology. This would require that universities establish curricula geared toward architectural education at a post-graduate level and that such programs be accessible to the urban, suburban, as well as the rural practicing professional.

### Environmental Hazards

Roof-top collectors employing glass or plastics as a cover material will be exposed to a number of natural hazards. These will include heavy winds and rain, hailstones, flying debris, tornados and hurricanes, and windblown sand. Certain portions of the country are more susceptible to potential damage from such natural phenomena and design solutions (using shutters, thicker glass, high density plastics) will have to be tailored to each respective region. Cost factors resulting from such actions will also create impacts that must be evaluated.

Air pollution such as industrial fallout and dust will adversely affect collectors by inhibiting insolation through the collector cover. Pollution can also be deleterious to the collector cover and may, in extreme cases, require its replacement due to resulting reduced efficiency.

### Political Impacts

Considerable influence is exerted by private interest groups relative to the limited impact exerted by private citizens. Because of their usually heavy financial support, such private interest groups tend to exert considerable influence on policy determination through their lobbying capability. Such special interest groups will be evident in the development of new energy systems, such as solar, and the demands and requirements of such groups will create significant impacts. Strong political opposition would result should an energy industry develop that attempts to limit or restrict the activities of these groups.

Among the myriad groups that have a direct effect upon energy policy formulation are government and private utility companies, energy producing companies (Exxon, Consolidated Coal, etc.) heating, ventilating and air conditioning equipment manufacturers and suppliers, energy producing states, energy producing land owners, and public and private conservation groups (Sierra Club, etc.).

Special interest group influence may be exerted at the local or state governmental level, but most influence is exerted at the national level.

A determining factor in the development of solar energy will be the level of state and local support as affected by the local economic base and the relative dependence upon revenues derived from fossil fuels. An analysis of fossil fuel production by states, Figure G.3.2-4, indicates that 26 of the 50 states produce significant levels of fossil fuel production and that Texas, Louisiana, California, and West Virginia are the only states which achieved in excess of 1,000,000,000 dollars worth of fossil fuel production in 1971, and only Kentucky, Oklahoma, Pennsylvania, Wyoming, and New Mexico achieved production levels in excess of 500,000,000 dollars.

It can be assumed that the political influences exerted by the 24 states that are energy dependent could be relatively strong in promoting solar utilization not only among themselves but also among the 17 states where fuel production may be large but not representative of a large portion of the states' economy.

Generally favorable attitudes toward solar energy development have been indicated by Congress and numerous bills have emerged from both the House and the Senate. These bills reflect the increasing awareness and concern at the national level for developing solar as an alternate energy source and resulted in the passage of PL. 93-409, the "Solar Heating and Cooling Act of 1974". Such an action is indicative of the potential effect of special interest groups and influence at the state and local levels.

#### Social/Psychological Impacts

A key factor in determining social/psychological impacts will be the resultant changes in life styles and in health and safety as a result of implementing solar technology.

The advent of solar energy will actually permit the consumer to maintain or increase his standard of living in a period when higher fuel costs have resulted in a declining standard of living. Since insufficient fossil fuel reserves exist to permit a continuously increasing standard of living and since it is not politically expedient to continually increase oil import levels, solar energy seems to offer a viable alternative that is more attractive than other potential sources (nuclear, coal) with their attendant environmental problems.

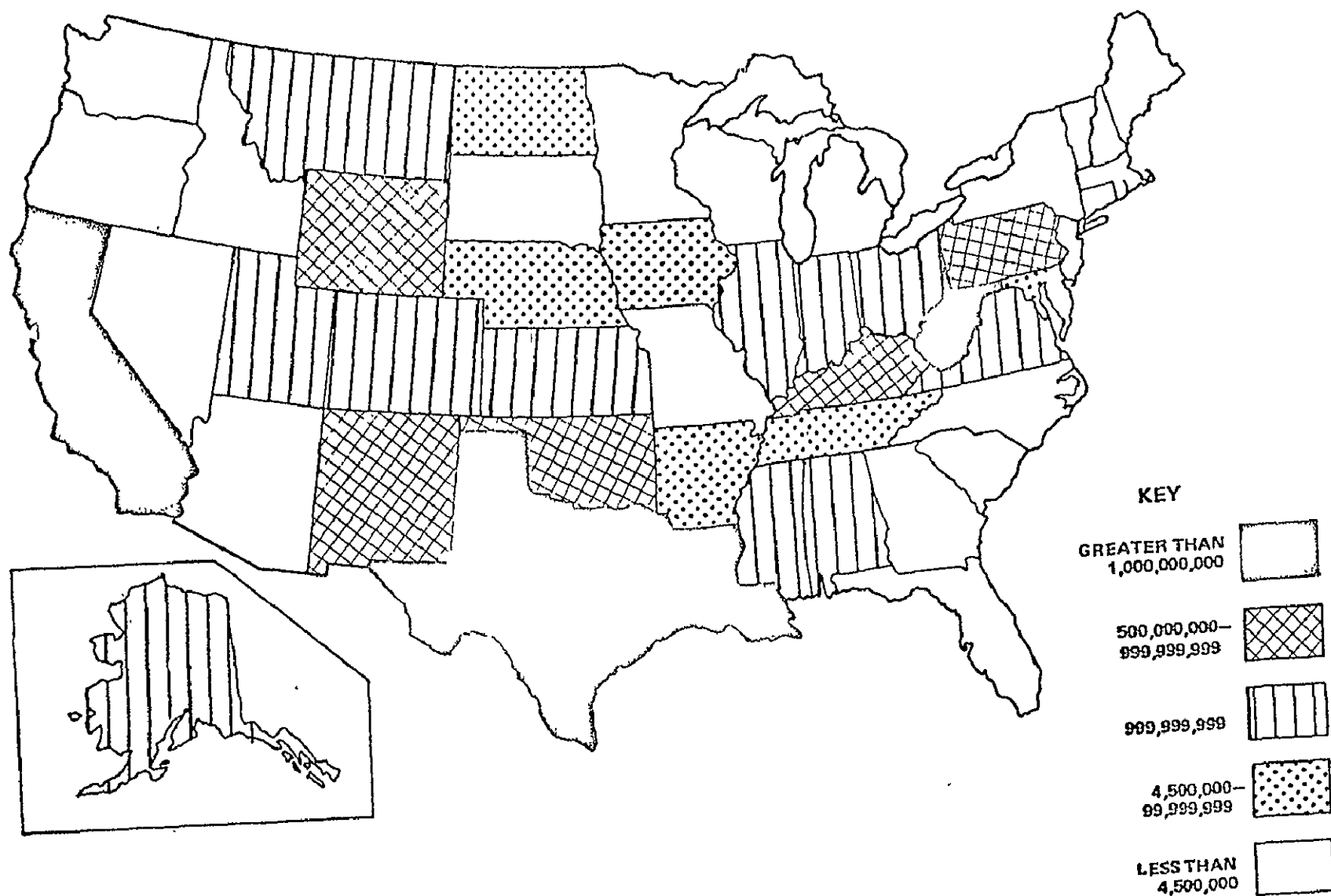


FIGURE G.3.2-4 TOTAL FOSSIL FUEL (PETROLEUM, NATURAL GAS, AND COAL PRODUCTION  
IN DOLLAR AMOUNT IN THE UNITED STATES BY STATE, 1971 [TERRASTAR-73]

One impinging factor that may cause impacts in lifestyles centers around the storage capability inherent in solar systems that may result in energy availability which may, in turn, result in lower heating levels at night or during inclement weather. An adjunct impact may be the need to alter bathing habits during such periods.

#### Utility Companies

Solar energy systems could be either beneficial or detrimental to energy producing companies. Should the utilities not participate, their sales may decrease or increase at a slower rate. On the other hand, it seems entirely likely that solar systems may require a supplementary source to provide power during periods of inclement weather when solar systems are not capable of maintaining adequate heating levels. Should the utility company be required to provide adequate power capacity to meet peak demands, capital investments may continue to increase while sales decrease.

Another alternative that may significantly impact the utility companies is rate structuring that would permit lower energy rates for off-peak hours. It may be beneficial for consumers who utilize solar systems to purchase low cost power at off-peak periods to "charge" their storage system to assure adequate availability at all times. Such an approach would be advantageous to the utility company in that it would permit "load leveling" or "peak shaving" that would result in greater efficiencies in the operation of power production equipment.

Utility companies are understandably more receptive to solar-electric generating stations than to individual heating and cooling installations. Such a system is readily adaptable to integration into their existing distribution system. The use of solar assisted heat pumps is also appealing to utility companies since such a system would allow the use of heat pumps essentially nationwide rather than only in areas with relatively mild winters. Use of the heat pumps also allows solar collector operating temperatures to be in the 100° F range permitting the use of less expensive collector units. The relative effectiveness of reduced operating temperatures is reflected in Table G.3.2-11. It is relatively obvious that the system requirements on the collector are significantly reduced resulting in lower collector costs per unit area.

It is entirely possible, when reliable solar hardware becomes available, that utility companies will install, maintain, and operate on-site solar systems in relatively large (district) complexes such as shopping centers, hospitals, schools, etc.

TABLE F.3.2-11 QUALITATIVE COMPARISON OF COLLECTOR REQUIREMENTS  
FOR SOLAR HEATING AND COOLING APPLICATIONS [SPENCER-75]

<u>COLLECTOR REQUIREMENT</u>	<u>SOLAR HEATING AND ABSORPTION AIR CONDITIONING</u>	<u>SOLAR-ASSISTED HEAT PUMP</u>
Glazings	2	1
Absorber Material	Copper, Aluminum	Galvanized Steel, Plastic
Absorber Coating	Selective	Flat Black



It is doubtful that utility companies will entertain such involvement in the residential sector due to such factors as lack of control, liability resulting from roof leaks and customer mobility. The economics of installing and maintaining numerous small units scattered throughout a community would probably not be economically beneficial.

The possibility of utility companies providing off-peak rates for auxiliary power to solar systems was previously discussed under "Social/Psychological Impacts". The specific rate will be dependent upon the operating characteristics of a particular utility. If the use of auxiliary power for solar heating systems reduces the revenues of utilities that peak during the summer without reducing the power availability required to meet peak air conditioning demands, the result will be an increase of the real costs of electricity regardless of the fact that consumption levels have been reduced. If, on the other hand, the utility peaks during the winter, the solar equipment may actually reduce the cost of electricity.

Gas utilities maintain greater interest in solar energy systems than do electric utilities. This is due to the fact that a major portion of the gas utilities revenues is attributable to residential space heating. In some areas of the country (Arizona), shortages in gas availability have resulted in curtailments to industrial customers who maintain a lower priority than residential customers. Gas utilities view solar systems as a means to provide some relief to the curtailments to industry.

Further evidence supporting the interest of utilities in solar energy systems is reflected in the fact that the Electric Power Research Institute, which is supported by the public utility companies and serves as a research agency for the industry, has initiated a solar energy research program.

### Conclusions

This section has attempted to present an analysis of impacts resulting from the institution of a specific action, i.e. "Implementing Solar Energy Systems". It is the purpose of this effort to demonstrate a methodological, holistic approach in assessing a particular action. Such a comprehensive analysis permits insights into seemingly superficial or impertinent factors that might be overlooked which may, in reality, have significant repercussions. Such an holistic approach is advocated in the analysis of any action regardless of how insignificant potential impacts may appear as the result of preliminary superficial evaluation..

Reference: MEGASTAR 74, TRW-Phase Zero Study

#### G.4 RESIDENTIAL/COMMERCIAL -- REDUCE ENERGY USE IN LIGHTING IN COMMERCIAL SECTOR

The following is a description of the use of a methodology in a comprehensive evaluation of a conservation action. The methodology utilizes components of both the systems approach and technology assessment and serves only as one suggested guideline among a multitude that could be used in the assessment.

Figure G.4-1 states the overall objective with a suggested set of requirements necessary to meet that objective. In order to accomplish the overall objective of reducing energy for lighting in the commercial sector a number of related individual actions were identified and qualitatively assessed as to their overall potential.

Listed in Table G.4-1 are the general constraints and criteria adopted by the Summer Research Faculty Group for use in the evaluation of various actions. Applying the constraints to the specific action requires a consideration of the political system and the extent that policy, codes, and standards may have to be changed in order to implement the action. Economic constraints relate to capital requirements for redesign, for incorporating new technology, etc. Among other things, social constraints relate to acceptance of building redesign and lower lighting levels.

There are several criteria that deserve special consideration. A reduction of lighting in the commercial sector will impact the peak loading problem since load factors will be reduced, especially in dense metropolitan areas where the potential for reducing consumption in commercial building is very large. Ease and time of implementation are certainly criteria against which the actions should be judged. Heavy technological requirements or long time periods for retrofitting or redesign could certainly deter from an otherwise favorable action.

In the systems approach, requirements for an objective in turn become individual objectives in a sub-systems diagram with their own set of requirements. For example, requirements for assessing the present situation include developing an overview, comparing standards and codes, and assessing efficiencies. The sub-system diagram for this task is depicted in Figure G.4-1. Likewise, requirements for sub-systems become objectives of sub-sub-systems diagram. Requirements for developing an overview means a consideration of present lighting usage in the residential/commercial sector, a comparison with total allocated electricity, and a development of unit demands for lighting compared to other appliances. Other requirements are necessary for a determination of standards and codes, and a consideration of present efficiencies. Some of these are depicted in Figure G.4-1 as sub-sub-systems.

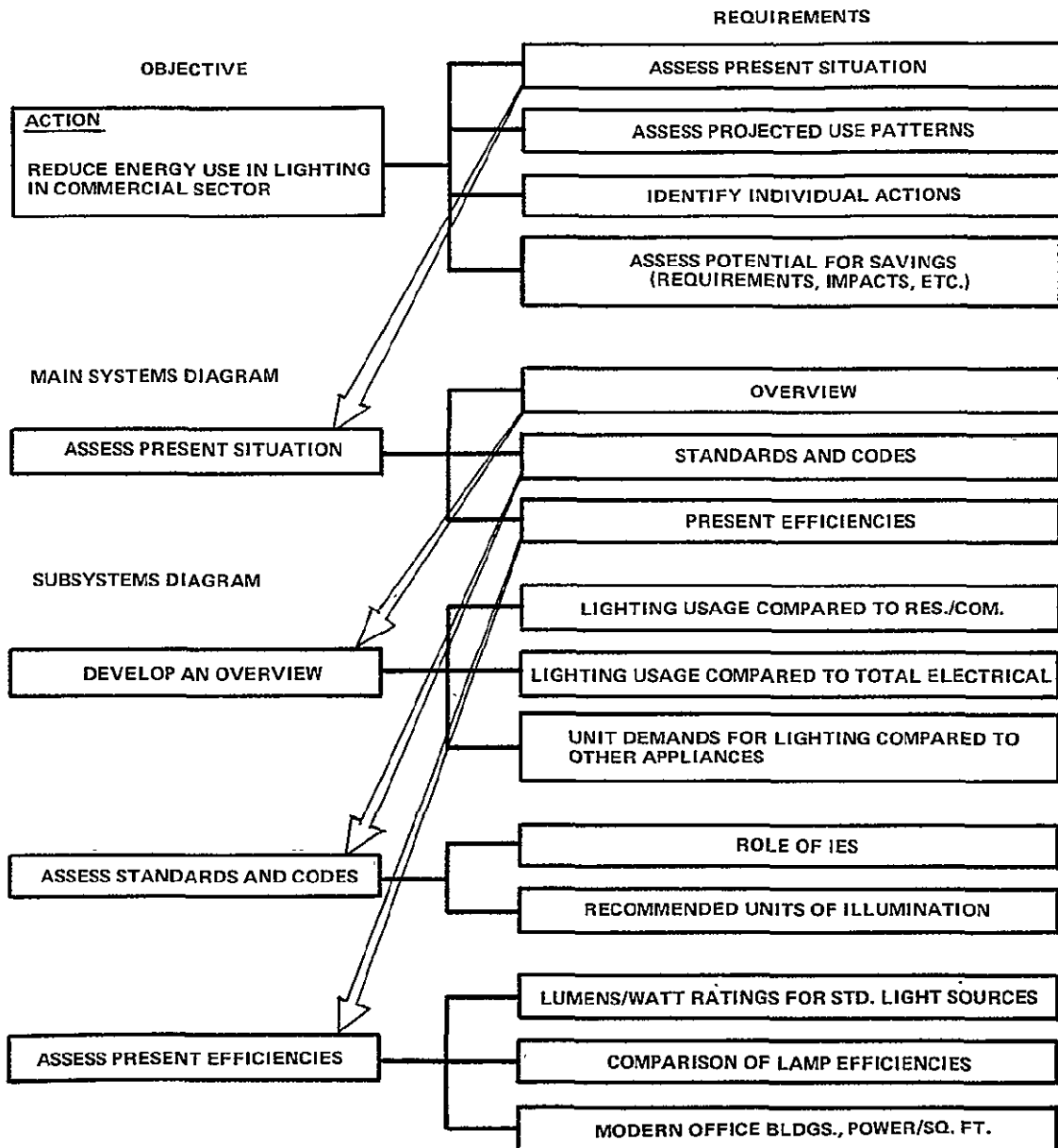


FIGURE G.4-1. SYSTEMS AND SUBSYSTEMS DIAGRAM FOR LIGHTING

TABLE G.4-1 GENERAL CONSTRAINTS AND CRITERIA USED IN ECASTAR

## CONSTRAINTS:

1. Political ex. Congressional lethargy
2. Economic ex. capital available, sunk costs (prior invest.)
3. Social ex. population growth rate
4. Must be technologically feasible ex. breeder technology
5. Available (but quantity unknown) resources ex. oil, manpower, etc.
6. Natural physical law ex. 1st and 2nd laws.

## CRITERIA: Will the proposal.....

1. Reduce dependence on non-domestic energy?
2. Have minimum or desirable environmental impact?
3. Have severe institutional impact?
4. Economic-feasible? And in time frame under consideration?
5. Social-feasible? (time frame)
6. Increase energy supply?
7. Reduce energy demand?
8. Political-feasible? (time frame)
9. Ease of implementation?
10. Impose hazards to human life or health?
11. Affect the energy supply mix?
12. Does the proposal improve the demand peaking problem?
13. Will the proposal reduce dependence on scarce fuels?

In order to assess projections of energy use for lighting, one must consider data from studies such as the Westinghouse Energy Utilization project, Project Independence, and National Petroleum Council. (see Figure G.4-2.)

The next step in the process was to identify individual actions under the heading of the general action. One means of accomplishing this task was to make use of a variety of information sources -- seminar speakers, reports (Project Independence, National Petroleum Council), think tank ideas, group interaction, etc. (see Figure G.4-3.)

From the various sources a number of actions were identified. These are listed in Table G.4-2 along with potential savings, ease of implementation, requirements, impacts, etc. In many cases, it was not possible to determine or document exact numbers, but the matrix serves as an example of a qualitative assessment of a number of individual actions.

It is obvious from a cursory examination of a number of the actions that large potential savings can be accomplished by mandating government standards for lighting in all new and existing commercial structures. Project Independence predicted significant savings based on programs conducted by the General Services Administration. For this reason, and because of time constraints within the Summer Faculty Program, the major action of mandating government standards for lighting in commercial buildings were compared with two parallel actions -- utilization of effective switching systems to reduce lighting requirements in the commercial sector and a redesign of building interiors and exteriors to maximize sunlight penetration from natural lighting (see Figure G.4-4.).

In order to assess the three chosen alternatives for reducing energy due to lighting in the commercial sector, it was necessary to filter the actions through a criteria evaluation matrix in order to determine requirements and impacts. Major constraints were time frame -- it was deemed necessary to consider the potential for immediate savings -- and cost of implementation. Table G.4-3 illustrates a qualitative evaluation of the three actions through the previous evaluation matrix used by the residential and commercial sector to filter all actions. In assessing the three alternative actions as to their overall potential for maximum savings in the near time period, the following considerations are noted:

Effective switching requires in some cases substantial retrofitting and subsequent manpower requirements;

Switches at strategically located places may not be properly used -- especially if incentives are not provided.

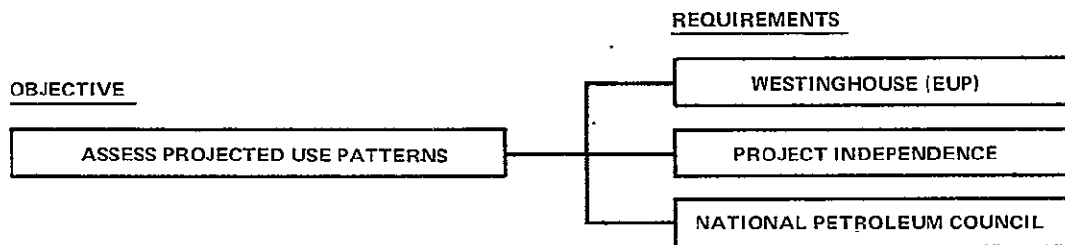


FIGURE G.4-2. SUB-SYSTEMS DIAGRAM FOR ASSESSING PROJECTED USE PATTERNS

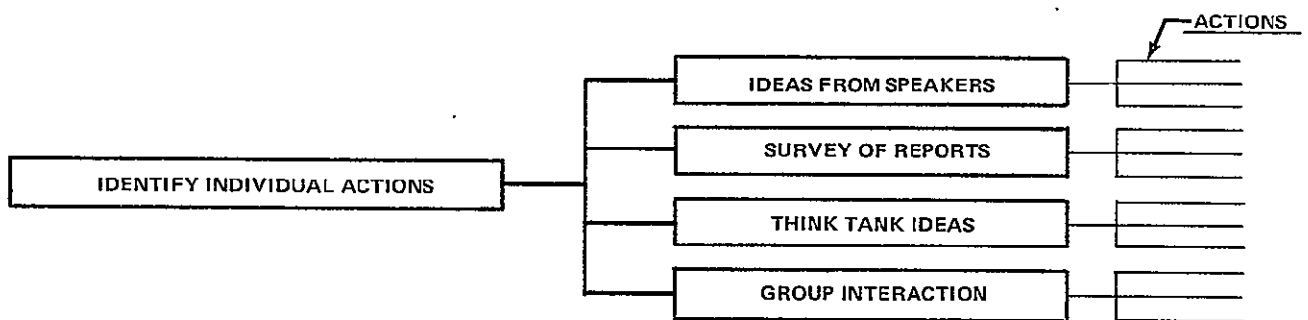


FIGURE G.4-3. SUB-SYSTEMS DIAGRAM FOR IDENTIFYING INDIVIDUAL ACTIONS

ORIGINAL PAGE IS  
OF POOR QUALITY

TABLE G.4-2. REDUCED LIGHTING  
CONSERVATION ACTIONS

Possible Conservation Actions Related to Reduced Lighting	Potential Savings	I-Very Easy, to IV-Very Difficult Ease of Implementation	Time Frame	Requirements for Action			Impacts of Action
		Category I, II, III, IV		Capital	Material	Manpower	
Plan spaces so that similar task areas are grouped or stack- ed	Small	III	Near	Small to Medium	Small to Medium	Small to Medium	-Impact on wiring systems, plumbing needs, etc. -Relativity of costs of planning and redesigning
Utilize effective switching systems - manual switches at properly located places - photocell switches to integrate natural and artificial light- ing - photocell to save lighting in exterior areas, parking lots, etc. - low voltage switches - time clock switches - with manual overrides - timed devices for bathrooms, corridors etc. - security lighting with intruder detec- tor switches - motion detection switches to activate lighting in stairways, stockrooms, etc.	Medium	II	Near <1985	Small to Medium	Small to Medium	Small to Medium	Requires some advances in tech- nology, capital to implement, and time for development
Redesign buildings interior and exterior to maximize sunlight penetration (natural lighting) Examples -- - add light reflective interior surfaces to	Small to Medium	III to IV	Near to Mid	Signi- ficant capital for re- design	Medium depends on extent of re- design	Medium needed in re- design- ing re- tooling	Psychological adjustment to dark corridors, etc. -changing of codes and stds. -must consider time of day and year, size and location of bldgs. and sky lights, ratio of inter- ior and perimeter areas, position shape, and color of interior

Possible Conservation Actions Related to Reduced Lighting	Potential Savings	I-Very Easy, to IV-Very Difficult Ease of Implementation	Time Frame	TABLE G.4-2. (cont'd) Requirements for Action			Impacts of Action
		Category I, II, III, IV		Capital	Material	Manpower	
increase efficiency of natural lighting - add reflective window sills						and implementing	partitions, floors and ceilings-furnishings. -impact of change on esthetics, HVAC, wiring, plumbing, mobility, etc.
Mandate government standards for lighting in all new and existing commercial structures - (50-30-10 footcandle standard)	2.7 trillion BTU's 1974 saved in government buildings  Total 50% or .65 quad for all commercial buildings	I	Near Term	estimated at \$25-50 million/yr. for adm. and compliance costs	Small	Small	Policy would require legislation and/or regulation -reduction in sales by bulb and lighting equipment manufacturers -higher increase in crime -impact on heating and cooling systems and practices -impact on wiring industry changes in manpower, materials capital requirements, etc. -impact on utility load load factor -impact on wet or dry heat of light systems
Design fixtures to cut glare and reflections	Low	II	Near	Small to Medium	Small	Small	-cost of redesign -cost of replacement -esthetics of redesigned fixture
Position lighting fixtures for maximum usefulness - use perimeter luminaires instead of continuous strips - place lighting fixtures between desks instead of over - place high intensity lights away from a task and conventional lights near - place lighting on side to reduce ceiling reflection	Low	II	Near	Small	Small	Small	-impacts on future availability to clients -impact on ceiling heights, building volume, and climate control systems -impact on cooling load -affect on artificial lighting requirements -effect of more windows on heat transmission and infiltration -demands on air conditioning due to direct solar heat gains -impact of glare controls, interior or exterior shade systems, additional wiring and/or controls, system to integrate

ORIGINAL PAGE IS  
OF POOR QUALITY



Possible Conservation Actions Related to Reduced Lighting	Potential Savings	I-Very Easy, to IV-Very Difficult Ease of Implementation	Time Frame	TABLE G.4-2. (cont'd) Requirements for Action			Impacts of Action
		Category I, II, III, IV		Capital	Material	Manpower	
							artificial and natural light sources.
Educate people on gen- eral housekeeping, use of new devices, etc.	Low (potential great but actual achievable may be very small)	II	Near	Small	Small	Small	-manpower needed in education process -success depends on ability to motivate to save, and external incentives such as higher utility bills
Schedule custodial work during normal working hours in comm- ercial buildings	Low	II	Near	Small	Small	Small	-hindrance to daytime workers -certain tasks impossible during day
Use year-round day- light savings time to coordinate daylight and working hours more closely	Low	II	Near	Small	Small	Small	-questionable as to extent of savings -significant social change -safety factors (school children)
Utilize concept of ESI (Equivalent sphere illumination or glare- free-foot-candle as a standard of measure- ment for lighting re- quirements	Small to Mid	I	Near	Small	Small	Small	-code change -retooling of architect, con- struction, engineer, etc.
Improve light output by effective clean- ing of luminaries, and replacing de- preciated lamps	Small	I	Near	Small	Small	Small	-maintenance requirement
Arrange lighting pro- grams for entire facilities to match business activities	Small to Mid	I to II	Near	Small	Small	Small	-cost of programming

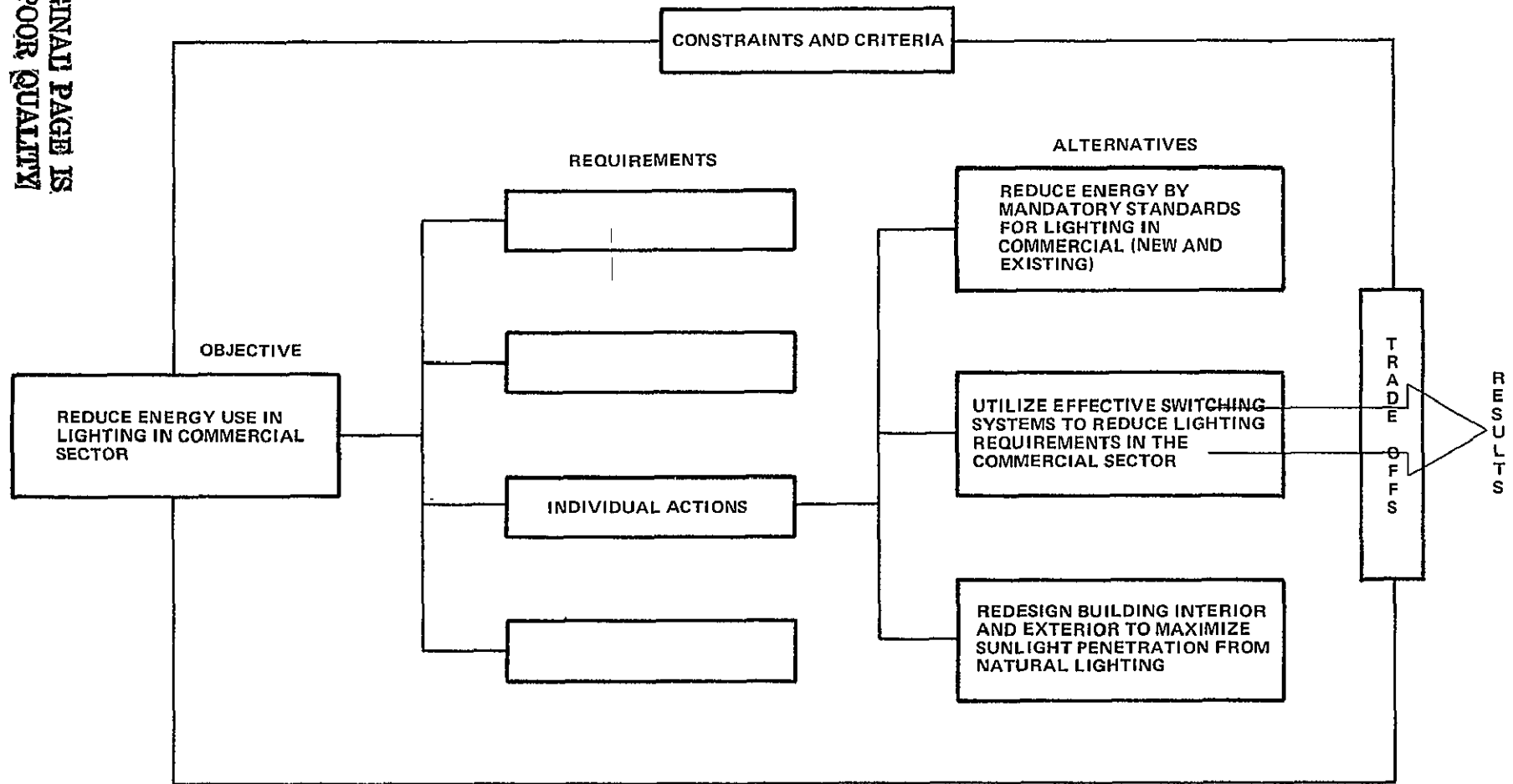


FIGURE G.4-4. ALTERNATIVES FOR LIGHTING

TABLE G.4-3. CONSERVATION ACTION EVALUATION MATRIX

CONSERVATION ACTION	POTENTIAL SAVINGS	EASE OF IMPLEMENTATION	AVAILABILITY			IMPACTS				OVERALL FEASIBILITY	COMMENT
			CAPITAL	MANPOWER	MATERIALS	SOCIAL	POLITICAL	ECONOMIC	ENVIRONMENTAL		
(1) Reduce energy by mandatory government standards for lighting in the commercial sector (new and existing)	+H	+H	+H	+H	+H	+L	-L	+M	+H	+H	(+) -positive or favorable (-) -negative or unfavorable H -High M -Medium L -Low +H =Highly favorable (requirements available, positive impacts)
(2) Utilize effective switching systems to reduce lighting requirements in the commercial sector	+M	+L	+L	+L	+M	+L	+H	+M	+H	+M	
(3) Redesign building interior and exterior to maximize sunlight penetration from natural lighting	+L	-L	-M	-L	-L	?	+M	+L	+M	-L	

Total savings from utilizing effective switching would not equal that of mandating the 50-30-10 footcandle standard. The action actually serves as one means of accomplishing this standard.

A redesign of building interior and exterior to maximize sunlight penetration may require extensive changing of codes and standards, significant impacts of natural sunlight on cooling loads, high materials requirements for redesign, considerations of glare controls, interior or exterior shade systems, additional wiring, and systems to integrate artificial and natural light sources.

A redesign of buildings to effectively use natural lighting would serve as one means of meeting the 50-30-10 footcandle standard. It should be kept in mind, however, that an improper utilization of natural lighting could impose a heavy load on HVAC systems and result in a greater energy requirement for the building.

The following are major points in the analysis of the action of mandating the 50-30-10 footcandle standard for the purpose of reducing lighting in all new and existing commercial buildings. (See section 7.5.3).

The Federal Energy Management Program, of which "delamping" or reducing lighting levels was the major emphasis, saved an estimated 2.7 trillion BTU's or \$760 million in fuel costs in fiscal year 1974.

Total savings after the establishment of mandatory federal standards, including federal monitoring and compliance mechanisms, would save an estimated .65-1.4 quads per year by 1980 -- 90 percent of which would be realized the first year.

Only small capital requirements are required by the commercial sector for implementation. However, an estimated \$25 to \$50 million per year would be spent at the federal, state, and local levels for compliance costs. Manpower and material requirements for the action would be small.

The action would result in some reduction of sales by bulb and lighting equipment manufacturers with a subsequent higher unemployment rate for these manufacturers.

Since the action would require federal, state, and local

legislation and/or regulation, there would be a need for enforcement personnel and additional maintenance people to implement the program.

Major considerations that complicate enforcement are: (1) control of lighting varies widely, depending on such factors as building ownership, management, and occupancy, (2) some new office buildings are designed with only one master breaker per floor or less -- restricting the ability to turn off lights in offices not used and (3) many offices are open for work on weekends and cleaning at night.

Reduced night-lighting could cause a higher incidence of crime and vandalism in some areas, resulting in increased expenditures for repair and increased security personnel.

One distinct advantage in reduced lighting would be the savings resulting from the subsequent decreased energy consumption due to the lessened demand for air conditioning.

Reduced lighting would have a significant effect on utility load factors, especially in large metropolitan areas.

In any action, there are unfavorable impacts and requirements that must be weighed against potential savings, time to implement action, etc. This is certainly true of the mandated 50-30-10 footcandle standard. Overall, however, this action is extremely favorable because it provides significant savings within a short time frame and with a minimum of requirements and negative impacts. In a trade-off with the other two actions the mandated 50-30-10 footcandle standard does not have the substantial capital, manpower, and material requirements that are necessary to redesign buildings. Neither does it require the long lead period that may be necessary to develop and/or incorporate the sophisticated switching systems used in the other action.

The following section is a summary of some background data used in evaluating the various actions.

### Present Situation

Project Independence [PI-74-1] presents the following data that is relevant to an assessment of the action:

Residential and commercial sector accounts for 32% of all energy consumption (18.1 quads in 1972).

Space heating -- 57%

Operational equipment -- 33%

Lighting -- 10% (1.8 quads)

Commercial consumption for lighting -- 73% or 1.3 quads

Assumed achievable savings in commercial -- 50%

In low-rise buildings without elevators, lighting can consume 60% of the supplied electrical power. In hot weather, lighting systems account for one-fourth to two-thirds of the cooling load in a typical office building. The enormous amount of electricity consumed by lighting fixtures is evident in the following example, cited in the report of the ad hoc Committee on Energy in Large Buildings to the Interdepartmental Fuel and Energy Committee of the state of New York: "In 1970, the electrical utilities in this country consumed energy equivalent to 8.14 million barrels of oil daily, or enough to fill four 500,000-ton supertankers. By 1985, utilities will use the equivalent of 23.58 million barrels daily at the present growth rates, or 10 supertankers. In 1975, 25 percent of this total electrical output was used for lighting systems. By 1985, this figure could grow to the equivalent of 5.985 million barrels of petroleum daily, or three supertankers every day for lighting alone."

#### Lighting Standards and Codes

Lighting in the United States is usually measured in footcandles, a gross measure of brightness that does not accurately indicate usable light levels. A person in a bright room may still be unable to perform his or her tasks because of surface reflections which effect a white veil between the viewer's eye and the task. When there is a complaint about insufficient lighting in a room, it often means that reflections or glare make work difficult and not that the overall room is too dark. In the past, the Illuminating Engineering Society (IES) has responded to such complaints by raising recommended footcandle levels. As a result some suggested lighting levels have more than doubled in the last 30 years. With lamps of equal efficiencies, this has doubled energy consumption. As shown in Table G.4-4, present recommended lighting levels are compared with those presented in IES's first handbook edition in 1947.

Foreign lighting standards historically have been somewhat lower than domestic standards, although there is a trend in most countries

TABLE G.4-4. RECOMMENDED LEVELS OF ILLUMINATION, BY SELECTED TASKS [PI-74]  
(foot candles)

Task	I.E.S. Lighting Handbooks					Industrial Safety Handbook (British)
	1947	1952	1959	1966	1972	1969
Conferring, Reading High Contrast Material	30	10	30	30	30	20
Reading or Transcribing Handwriting, Good Con- trast	30	--	70	70	70	
General Office Work, Reading Good Reproduc- tions	50	30	100	100	100	50
Bookkeeping	50	50	150	150	150	
Drafting	--	--	200	200	200	75
Corridors, Stairways	10	5	--	20	20	10

Arthur D. Little, Inc.

toward higher levels. For comparison, Table G.4-4 shows current British recommendations for office lighting.

The IES recommendations should not be confused with a mandatory code, nor do they necessarily indicate the present lighting levels in buildings. Nevertheless, architects and engineers generally follow the guidelines set by IES.

It appears that in the United States the lighting level selected is the one recommended for the most difficult expected task and the general illumination is then brought up to that particular level. This approach undoubtedly has accounted for the high lighting demands in commercial construction.

Indications from the design professions indicate that closer scrutiny is being given to the use of IES recommendations for energy conservation. It appears to be more practical to provide general illumination compatible with general activity, and to supplement local lighting as needed. Whether this and other energy-oriented trends will be promulgated by IES is a point of conjecture; however, there appears to be a trend toward an overall lowering (and certainly a plateauing) of lighting levels within new construction.

### Present Efficiencies

Source (lamp) efficiency is directly related to the lumens produced per watt of power input. The lumens per watt ratings of standard artificial light sources are:

<u>Light source</u>	<u>Lumens/watt</u>
Incandescent	17 to 22
Mercury	56 to 63
Flourescent	67 to 83
Metal halide	85 to 100
High-pressure sodium	105 to 130

Energy conservation standards for building lighting are being written in terms of installed power per square foot of building floor area. Modern office buildings typically install 2.5 to 5  $W_e/ft^2$ , whereas the new "1974 General Services Administration Public Service Building Energy Conservation Guidelines" recommends 1 to 2  $W_e/ft^2$ .



and the energy-conserving Federal Office Building in Manchester, New Hampshire, actually uses  $0.7 \text{ W}_e/\text{ft}^2$ .

The efficiency with which light is conveyed to any horizontal surface, as opposed to being absorbed on fixtures and walls, can be estimated. A building equipped with  $2.5 \text{ W}_e/\text{ft}^2$  in the form of 40-W fluorescent bulbs will emit 197 lm per  $\text{ft}^2$  of floor area, at least double the 80 to 100 lm/ $\text{ft}^2$  figure quoted. Thus about half of the lumens don't find their way down, either directly or via reflections.

#### Projected Use Patterns

Project Independence (Figures G.4-5 and G.4-6) compares lighting requirements in residential and commercial sector with other end use demands through the year 1990.

National Petroleum Council -- The National Petroleum Council study projects that reducing lighting levels in the commercial sector has a total potential savings of .292 quads in 1978, but only an assumed achievable of .096. In light of recent programs conducted by the General Services Administration, this figure appears to be extremely low. The potential for savings by reducing lighting in the commercial sector is extremely large if the action is mandated.

Westinghouse -- The Energy Utilization Project -- lists projections on lighting requirements through the year 2000 in the residential sector. In their base case projections for the commercial sector, lighting requirements increase from a 1972 level of .560 quads to .864 in 1985 and 1.352 quads in the year 2000.

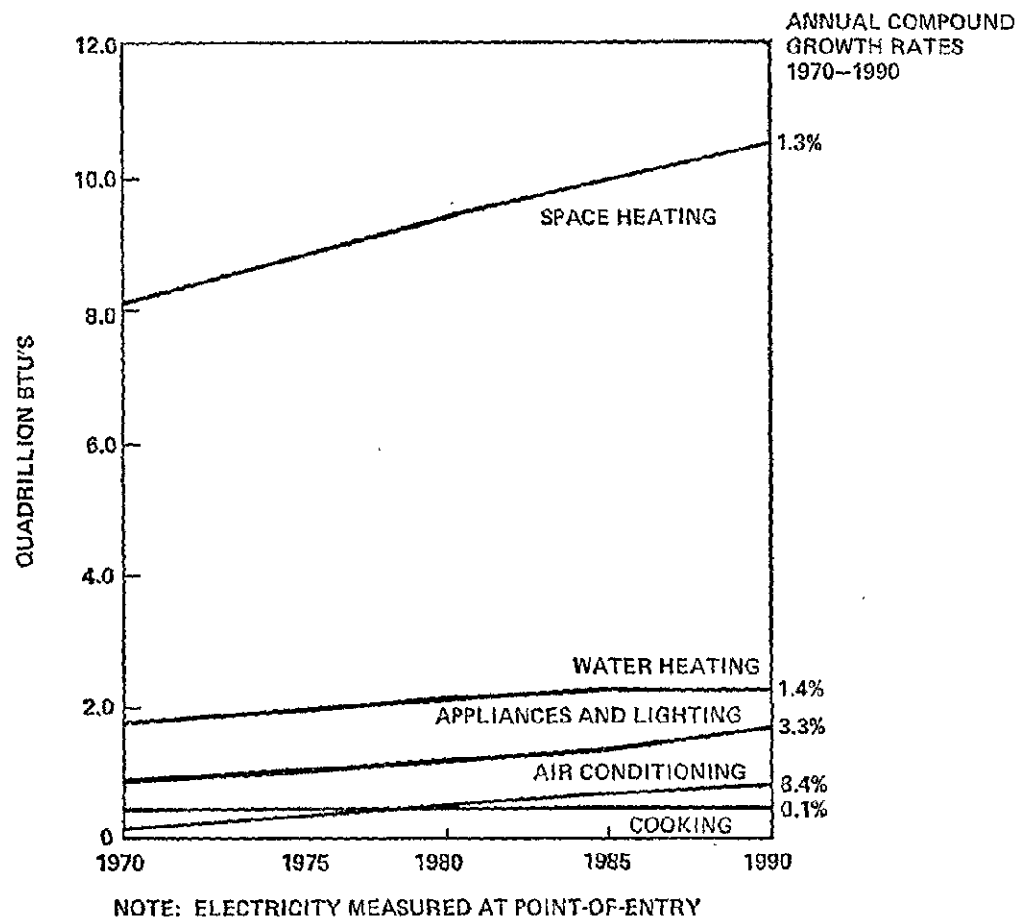


FIGURE 6.4-5. 1970-90 GROWTH IN RESIDENTIAL ENERGY DEMAND BY END USE [PI-74-5,18]

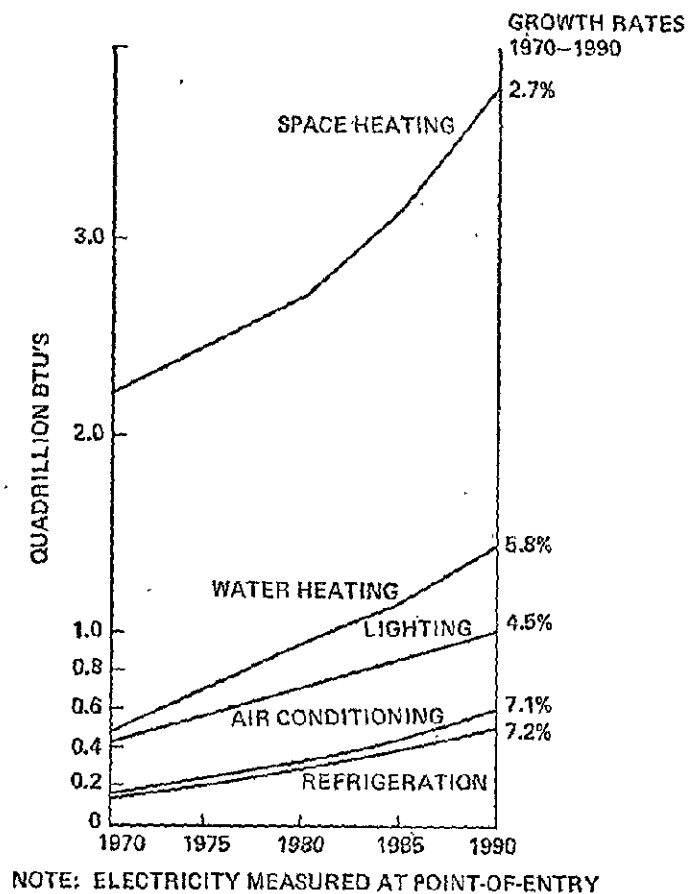


FIGURE 6.4-6. 1970-90 GROWTH IN COMMERCIAL ENERGY DEMAND BY END USE [PI-74-5,19]

## G.5 RESIDENTIAL/COMMERCIAL REDUCED CONSUMPTION AND INCREASED EFFICIENCY OF RESIDENTIAL HOT WATER SYSTEMS

In 1970, 1.7 quads or 15% of the residential energy consumption was used for hot water heating. Under the assumption of no major technological, price, or governmental policy change, consumption for 1985 is projected to be 2.3 quads [PI-74-1]. It is felt that these magnitudes warrant actions to reduce them.

### G.5.1 REDUCE USE OF HOT WATER

The analyses of three significant actions are presented below as examples. They are: reduce use of hot water, reduce storage temperature, and increase storage insulation. Determination of the quantitative values are given in Appendix G.5.6 through G.5.10.

A large quantity of heat energy is required to raise the temperature of water from the pipeline value to the 160°F, typical for hot water heaters. By reducing the amount of hot water used, this energy is saved. For each gallon of reduced usage of hot water, approximately 750 BTU's are conserved; because of present day inefficiencies, this value translates back to between 1500 and 2200 BTU's of fuel. Quantities of hot water may be saved by shorter duration showers or by using water for baths from the hot water faucet only, until the desired temperature is achieved, and to maintain it. A second family member subsequently using the same water or bathing small children together approximately halves the water and energy used.

By reducing the tub level one inch (considered half hot, half cold) for each family unit of four taking an average of two baths per week, the annual savings would be about seven dollars per year. It is recognized that for larger families and/or members taking a greater number of baths the saving will be proportionally greater. This savings and the potentials for energy and dollars, projected to national levels for 1972 and 1985, are given in Table G.5-1.

Realization of the potentials given in Table G.5-1 would require 100% participation of all family units. The expected cooperation of the units have been studies [NPC-74] for various communication levels used by the program. The achievable potentials (in percent) are presented in Table G.5.-2. The projections are also given for actions discussed below.

By using cold water detergents, the energy used to heat the water is saved. For a family averaging three loads per week, the savings would be twelve dollars per year, compared to that using the warm cycle. If the hot cycle had been used, the saving is doubled. The projected national savings, compared with previous use of the warm cycle, is

TABLE G.5 -1. FAMILY AND NATIONAL POTENTIAL SAVINGS FOR CONSERVATION ACTIONS

## IN RESIDENTIAL HOT WATER SYSTEMS

Potentials Conservation Actions for Residential Hot Water Systems		Dollars saved each year by family unit	National per annum Conser- vation (Quads)	National Conser- vation (10 <sup>3</sup> bbl/ da if produce by oil).	Improved Balance of Payments (if imported) in "\$" billions
Reduced tub water level one inch or equiv. for shower	1970 1985	6.00	.13 .17	62 81	.27 .35
Use Cold Water Detergents.	1970 1985	92.00	.29 .38	138 174	.59 .77
Replace washer in leaking hot water faucet (est. two per family unit.	1970 1985	5.00	.08 .10	20 26	.09 .12
Reduce hot water systems thermostat to: 140 F (w/dish- washer)	1970 1985	14.00	.33 .43	160 210	.68 .89
120 F (No/dish- washer)	1970 1985	16.00	.36 .47	174 228	.75 .98
120 F (dish- washer set for 140)	1970 1985	22.00	.51 .67	247 323	1.00 1.31
Enclose Entire Hot Water storage tank with three inches of (taped on) insulation	1970 1985	12.00	.29 .38	140 183	.76 .99
TOTALS (for 140 F Thermostat, using dishwasher once a day)	1970 1985	49.00	1.12 1.47	531 695	3.14 4.11

TABLE G.5-2. EXISTING RESIDENCES-ACHIEVABLE (IN FIVE YEARS)  
 CONSERVATION POTENTIALS (PERCENT PER YEAR OF TOTAL  
 POTENTIAL) [NPC-74]

CONSERVATION ACTION	COMMUNICATION LEVEL	YEAR OF PROGRAM				
		1	2	3	4	5
Reduce bath water used	low	2	3	4	5	6
	med	3	5	6	7	8
	high	5	7	8	9	10*
Use cold water detergent	low	10	25	50	70	80*
	med	20	40	70	80	80
	high	30	50	80	80	80
Set water heaters thermostats	low	4	8	12	16	24
	med	7	14	21	28	35
	high	8	18	27	36	43*

\*Max. assumed achievable.

also given in Table G.5-1. It is felt that public acceptance of this practice will readily come via normal commercial advertisements. Estimates are given in Table G.5-2. Although the dollar cost of cold water detergents is comparable to the other types, it could be that the energy cost (in their production) could, on a national level, diminish or even cancel the net energy savings (cf. Section 3.4).

Hot water faucets are usually the ones that drip. This is true for two reasons: 1) the faucet seat contracts on cooling (after the water is shut off); 2) the washers degrade faster because of the elevated temperature. A typically small leak (e.g., one-half cup in one hour) wastes 200 thousand BTU's per year at a cost of about two and one-half dollars to the family for each leaky hot water faucet. The savings for an estimated two per family unit, with projections, are shown in Table G.5-1. The percents achievable for the first five years of a national program are given in Table G.5-2.

#### G.5.2 REDUCE STORAGE TEMPERATURE

By reducing\* the thermostat setting on hot water storage tanks from 160°F (typical value set at factories) to 140°F, energy is saved by reducing the heat lost through the tanks' insulation. In dollars the savings is approximately eight dollars per year.

Less energy is required to raise water to 140°F than 160°F. For a dishwasher, if used once a day, the energy saving in dollars is about six dollars per year. For other uses, such as a bath or clothes wash, more of the 140°F water is required, when mixed with the cold, to achieve a desired water temperature, so there is no net energy saved.

If the water is not needed for a dishwasher, or if the dishwasher has a booster set for 140°F, the hot water system thermostat can be set for 120°F\*\* This second 20° reduction again reduces the heat loss through insulation, and the total family savings is sixteen dollars per year. For families using dishwashers with boosters set at 140°F versus the originally 160°F water coming straight from the residential hot water system, an additional six dollars (as discussed in the preceding paragraph) are saved, for a total of twenty-two per year. The dollars and BTU's savings for the thermostat settings are given in Table G.5-1. Achievability estimates are given in Table G.5-2.

\* There are two thermostats on electric hot water tanks; each is accessible by removing plates secured by screws. The thermostats are usually covered by insulation (e.g., fiberglass). To avoid exposure to bare electrical wires, push this insulation aside with a plastic instrument or wooden stick.

\*\* Even if the water is used for a dishwasher, which typically requires about 12 gallons of water straight from the hot water tank, for tanks of capacity 40 gallons or more, the lower thermostat can be set at 120°F giving about one-half the gain.

### G.5.3 INCREASE STORAGE INSULATION

Because of first cost (selling price) competition, only the best hot water heaters have as much as two inches of insulation (e.g., as fiberglass). By adding to the outside three inches of insulation (R-11) batting, carefully taped on so as to completely enclose the hotwater storage unit, there is a great reduction in the heat loss through the increased, total insulation. For tanks set at 160°F, the energy savings are almost two million BTU's per year. For a tank set for 140°F, the family's annual savings would be twelve dollars per year. The summary for this action is also presented in Table G.5-1. A fifty gallon tank has been considered in each case; its area is less than 30 sq. ft., including top and bottom; three inch insulation costs about four dollars. It can be secured using wide masking tape.

### G.5.4 IMPACTS

Lower hot water temperatures reduce the probability and seriousness of a child's being burned. Water temperatures of 140°F and the bactericidal action of dish washer detergents are adequate for removal of pathogenic bacteria if the dishes are not allowed to sit before rinsing [Johnson-75]. There has been insufficient study to insure safety at lower temperatures.

Adding insulation to the hot water tank is the only action presented which has material requirements. If all the tanks in the approximated 70 million family units (1972) were insulated using 30 sq. ft. each, approximately 2 trillion sq. ft. of insulation would be required. If this was accomplished over 5 years, the 0.4 trillion required each year would have minimal effect on the supply now furnishing approximately 10 trillion sq. ft. for new houses.

The largest saving results from improved storage tank insulation; this means the storage tank cools much slower, and the system would require little power during the daytime. This is reasoned because hot water drawn for dishwashers at night and bathing later would be reheated during the night. Thus, for electrical systems, the actions would improve the utilities load factor while conserving energy.

### G.5.5 ASSUMPTIONS

The typical family unit is considered to have a 50 gallon hot water heater; from estimates of a 1.5 ft. diameter and a 4 ft. height, the outside area was calculated to be 27 sq. ft. Inlet water temperature was conservatively taken as 70°F; the actions would effect greater savings for a lower value.

The typical family size is taken as having four members, the 1970 residential inventory as 68 million, the 1985 as 89 million [PI-74].

Dollar savings were determined assuming an electrical hot water heater, 75 percent efficient, and electrical cost of \$.03 per kWh. The overall efficiency of electrical systems is taken at 33 1/3 percent, such that the ratio of BTU fuel in to BTU's delivered to the consumer is 3.

The heat value of a barrel of oil is assumed to be 5.8 million BTU's, and if imported, the cost is 12 dollars per barrel (1972 stat.).

#### G.5.6 ENERGY SAVED BY REDUCED WATER LEVEL IN BATH

For a tub 4' x 1.5', area = 6 sq.-ft., each 2 inches of water depth is one cubic foot or approximately 8 gallons of water. Thus a reduction in water level of one inch is equivalent to 4 gallons or approximately 2 gallons of hot water (e.g. 140°F mixed with water from a 70° F pipe line).

$$\text{Energy 'saved} = 2 \text{ gal.} \times 8.3 \frac{\text{lbs.}}{\text{gal}} \times (140 - 70) \times 1 \frac{\text{BTU}}{\text{lbs.}}$$

$$= 2 \frac{\text{gal}}{\text{bath}} \times 581 \frac{\text{BTU}}{\text{gal}} = 1162 \text{ BTU/bath}$$

$$1162 \frac{\text{BTU's}}{\text{bath}} \times \frac{4 \text{ persons}}{\text{family}} \times \frac{2 \text{ baths}}{\text{person/wk}} \times \frac{52 \text{ wks.}}{\text{year}} =$$

$$0.5 \frac{\text{million BTU's}}{\text{year-family}}$$

Dollar savings per family

$$\frac{0.5 \times 10^6}{3412} \frac{\text{BTU/family}}{\text{BTU/kw. hr.}} \times \frac{\$.03/\text{kw hr.}}{.75 \text{ (heater eff.)}} = \$6.00/\text{yr.}$$

In 1972:

$$0.5 \frac{\text{Million BTU's}}{\text{yr./family}} \times 68 \text{ million families} = 34 \text{ trillion BTU's}$$

Considering that the overall electrical system to residence is 33% efficient\*

$$\frac{34 \times 3}{.75 \text{ (heater eff.)}} = 130 \text{ trillion BTU's/yr. or } 0.13 \text{ Quads of fuel per yr.}$$

$$\frac{10^{15} \text{ BTU/Quad/yr.}}{5.8 \times 10^6 \text{ BTU/bbl} \times 365 \text{ das/yr.}} = 473,500 \text{ bbl's/da/Quad/yr.}$$

or .13 X 473,500 = 62 thous bbl/da.

\* Please refer to assumptions, G.5.5.



Considering oil at \$12 per bbl (if imported),

$$\frac{10^{15} \text{ BTU's/Quad/yr.}}{5.8 \times 10^6 \text{ BTU's/bbl}} \times \$12/\text{bbl} = 2.07 \text{ Billion dollars/Quad/yr.}$$

or  $2.07 \times .13 = .27 \text{ Billion dollars/yr.}$

#### G.5.7 ENERGY SAVED BY USING COLD WATER DETERGENTS

A typical automatic clothes washer used approximately 25 gallons of hot water on the hot cycle, 12 on the warm. To be conservative the latter is used, and three loads per week per family.

From the 581 BTU's/gal. compared with the warm cycle,

$$\begin{aligned} \text{Energy saved} &= \frac{581 \text{ BTU/gal.}}{.75 \text{ htr eff.}} \times \frac{12 \text{ gal}}{\text{load}} \times \frac{3 \text{ loads}}{\text{wk./family}} \times \frac{52 \text{ wks}}{\text{yr.}} \\ &= 1.45 \text{ million BTU/family} \end{aligned}$$

Dollars saved (elec. supply.)

$$\frac{1.45 \times 10^6 \text{ BTU}}{3412 \text{ BTU/kw hr.}} \times \$0.03/\text{kw hr.} = \$12.75/\text{yr.}$$

National savings, BTU's of fuel (based on '72 stat.)

$$\begin{aligned} 1.45 \times 10^6 \text{ BTU} \times 3^* \times 68 \times 10^6 \text{ family units} \\ = .296 \times 10^{15} \text{ BTU or .29 Quads.} \end{aligned}$$

The bbl's/da and balance of trade dollars given in Table G.5-1 can be readily determined using the relations between them and quads as developed in Section G.5.6.

#### G.5.8 ENERGY SAVED BY REPLACING WASHERS

Typical small leak: one-half cup per hour.

$$\begin{aligned} \text{Energy saved} &= \frac{1}{2} \frac{\text{cup}}{\text{hr.}} \times \frac{8 \text{ oz}}{\text{cup}} \times \frac{1}{128 \text{ oz/gal}} \times \frac{581}{.75 \text{ (eff)}} \frac{\text{BTU}}{\text{gal}} \times \frac{8760 \text{ Hrs}}{\text{yr.}} \\ &= 213 \times 10^3 \text{ BTU's/yr.} \end{aligned}$$

For two faucets per family  
over 400,000 BTU's/yr.

The other data for Table G.5.1 can be determined by using the factors developed earlier.

\* Please refer to assumptions, G.5.5.

## G.5.9 REDUCE THERMOSTAT

Consider a 50 gal. tank and thus approximately a total area of 27 sq. ft., also conservatively 2 inches insulation  $R=7$ ; first calculate the heat loss for  $T = 160^\circ \text{ F}$ , and an ambient temperature of  $70^\circ \text{ F}$ ,

$$H_{\text{loss}} = \frac{160 - 70}{R=7} \times 27 \times 8760 \frac{\text{hrs}}{\text{yr}}$$

$$= 3 \text{ million BTU's/yr.}$$

For  $T = 140^\circ \text{ F}$

$$H_{\text{sav}} = 3 \times 10^6 \frac{\text{BTU's}}{\text{yr}} \left( 1 - \frac{140-70}{160-70} \right)$$

$$= 670,000 \text{ BTU/yr.}$$

Since dishwashers use only hot water (approx. 12 gals. each day) the  $20^\circ$  reduction effects a saving in less energy to the water.

$$H \text{ saved per gal} = 20^\circ \text{ F} \times 8.3 \frac{\text{lbs.}}{\text{gal.}} \times 1 \frac{\text{BTU}}{\text{lb-F}}$$

$$= 166 \text{ BTU/gal.}$$

Total dishwasher savings per year, one load per day,

$$H_{\text{sav}} = \frac{166}{.75 \text{ (eff)}} \text{ BTU/gal} \times 12 \frac{\text{gal}}{\text{da}} \times 365 \frac{\text{Days}}{\text{yr.}}$$

$$= 970,000 \text{ BTU/yr.}$$

Total savings:

$$\begin{array}{l} 670,000 - \text{reduced loss through insul.} \\ 970,000 - \text{reduced energy to water} \\ \hline 1,640,000 \text{ BTU/yr.} \end{array}$$

Again the other data in the table are readily determined using the factor developed earlier.

## G.5.10 ADDED INSULATION TO HOT WATER STORAGE TANK

In the preceding section it was determined that the heat loss with two inches insulation ( $R=7$ ) was three million BTU's per year for  $T=160^{\circ}\text{F}$ ;  $T=140^{\circ}\text{F}$  gives a 670,000 BTU's per year saving. Thus at  $T=140^{\circ}\text{F}$ , the loss through the insulation is 2,330 thousand BTU's per year.

By adding three inches insulation (taped on outside the tank's metal cover), the total insulation gives  $R=17$ . The new heat loss is, for  $T = 140^{\circ}\text{F}$ .

$$H_{\text{loss}} = 2,330,000 \times \frac{7}{17}$$

$$= 1 \text{ million BTU/yr.}$$

$$H_{\text{saved}}: \quad 2.33 \times 10^6 - 10^6 = 1.33 \times 10^6 \frac{\text{BTU}}{\text{yr.}}$$

As calculated in earlier sections, this saving results in a twelve dollar reduction in the electrical utility bill (calculated on 3 cents per kw hr.).

## APPENDIX H. ECASTAR ENERGY INPUT-OUTPUT MODEL

The ECASTAR energy input-output model was constructed by aggregating the input-output model published in the 1974 issue of the Survey of Current Business. The transactions' matrix is reprinted in this Appendix, Table H-1.

Table H-2 identifies how the aggregation was accomplished. Transactions for electric utilities, gas utilities, and water and sanitary services were obtained from BLS Bulletin #1831.

Direct energy transactions for coal, crude, refined petroleum, electric and gas were obtained from (CAC-75). Using this data, BTU's per unit of total output were computed for all 30 groups. BTU's were distributed through the transactions' matrix by multiplying an industry's sales by its BTU per dollar output ratio. The direct and total requirements' matrices were computed in a similar manner.

TABLE H-1 INPUT - OUTPUT TRANSACTIONS' MATRIX  
(in millions of 1967 dollars)

Industry No.	For the distribution of output of an industry, read the row for that industry.  For the composition of inputs to an industry, read the column for that industry.	Livestock and livestock products	Other agricultural products	Forestry and fishery products	Agriculture, forestry and fishery services	Iron and ferroalloy ore mining	Nonferrous metal ore mining	Coal mining	Crude petroleum and natural gas	Stone and clay mining and quarrying	Chemical and fertilizer mineral mining	New construction	Maintenance and repair construction	Ordinance and aerospace	Food and kindred products
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Livestock and livestock products.....	5,010	1,448	95	189							80	3		19,777
2	Other agricultural products.....	8,379	905	105	507										8,682
3	Forestry and fishery products.....			31	45							161	19		1,123
4	Agriculture, forestry and fishery services.....	653	1,335			92	4	(*)		5	1				
5	Iron and ferroalloy ore mining.....					33	213								
6	Nonferrous metal ore mining.....					5	1								
7	Coal mining.....	4	1		(*)	(*)	1	400		6	(*)				34
8	Crude petroleum and natural gas.....					4	5	1	374						
9	Stone and clay mining and quarrying.....	2	119			4	5	3		53	7	670	261		8
10	Chemical and fertilizer mineral mining.....		12				3			61					
11	New construction.....														
12	Maintenance and repair construction.....	233	370			30	16	23	476	18	8	20	4	24	237
13	Ordinance and aerospace.....													764	
14	Food and kindred products.....	3,094		24	44										11,874
15	Tobacco manufactures.....														
16	Textile mill and narrow fabrics, yarn and thread mills.....		9			1		13				18	3	7	3
17	Miscellaneous textile goods and floor coverings.....	10	29	59	48	1	(*)	2	5	2		204	(*)	4	17
18	Apparel.....											49			15
19	Other fabricated textile products.....	(*)	43	(*)	5			3		11		1		7	27
20	Lumber and wood products, except containers.....	3	3			4	11	22			1	4,550	308	78	7
21	Wooden containers.....		105		13										110
22	Household furniture.....											313	8	(*)	
23	Other furniture and fixtures.....	15	1	(*)	(*)		(*)		1	21	1	217	43	5	253
24	Paper and allied products, except containers.....	2	3		123	(*)	(*)	(*)	(*)	(*)	1				1,700
25	Paperboard containers and boxes.....			(*)	(*)	(*)	(*)	(*)	(*)	(*)					501
26	Printing and publishing.....	75	2,107	3	21	28	50	50	164	48	(*)	3	(*)	18	403
27	Chemicals and selected chemical products.....														83
28	Plastics and synthetic materials.....	54								(*)					2
29	Drugs, cleaning and toilet preparations.....											456	608	2	4
30	Paints and allied products.....	167	605	36	5	4	5	35	33	74	3	1,400	624	26	214
31	Petroleum refining and related industries.....	37	185	5	(*)	15	9	27	33	29	9	611	108	83	683
32	Rubber and miscellaneous plastics products.....														(*)
33	Leather tanning and industrial leather products.....	9			1										1
34	Footwear and other leather products.....	8													1,001
35	Glass and glass products.....	2	25	(*)	(*)	1	3	11	83	110		163	67	15	
36	Stone and clay products.....					42	41	42	120	51	18	6,177	647	12	
37	Primary iron and steel manufacturing.....	1	1			4	1	8		5	2	1,458	290	523	13
38	Primary nonferrous metal manufacturing.....	15	9	39								2,155	209	298	5
39	Metal containers.....														1,040
40	Heating, plumbing and structural metal products.....				(*)	(*)		48		3	2	7,790	1,241	5	
41	Stampings, screw machine products and bolts.....	28			2	2	6	1		(*)	(*)	51	19	151	194
42	Other fabricated metal products.....	32	45	9	14	4	4	13	63	13	1	1,531	384	146	279
43	Engines and turbines.....				3			9	49	24	1	91	(*)	8	
44	Farm machinery and equipment.....	8	229												(*)
45	Construction, mine and oil field machinery.....					26	23	101	57	21	11	120	18	15	
46	Materials handling machinery and equipment.....					1	1	1	5	8	1	420	130	1	10
47	Metalworking machinery and equipment.....									1	1	2	(*)	95	1
48	Special industry machinery and equipment.....														61
49	General industrial machinery and equipment.....			(*)	4	(*)	51	8	80	17	(*)	170	38	1	102
50	Machinery shop products.....	5	5			1				4	5	42	6	100	(*)
51	Office, computing and accounting machines.....														
52	Service industry machines.....											602	163	15	
53	Electric industrial equipment and apparatus.....					1	1		162	6	2	410	51	2	
54	Household appliances.....											148	176	17	
55	Flexible lighting and wiring equipment.....	2	2	(*)	(*)	(*)		8	5	(*)	(*)	1,248	285	1	5
56	Radio, television and communication equipment.....											63	50	251	
57	Electronic components and accessories.....													232	
58	Miscellaneous electrical machinery, equipment and supplies.....	12	38	2		1		1	(*)			44	7	4	2
59	Motor vehicles and equipment.....	7	7			6							3	1	50
60	Aircraft and parts.....				(*)										1,269
61	Other transportation equipment.....	(*)	7	16	1	(*)	(*)	(*)			(*)		(*)	24	4
62	Scientific and controlling instruments.....											279			11
63	Optical, photographic and photoreproductive equipment.....														83
64	Miscellaneous manufacturing.....	2	2	4	(*)	(*)	1	(*)	(*)	(*)	(*)	111	91	5	9
65	Transportation and warehousing.....	690	452	40	27	103	65	28	5	26	15	2,135	478	89	2,592
66	Communications except radio and TV broadcasting.....	75	71			2	8	12		1	4	204	45	103	267
67	Radio and TV broadcasting.....														
68	Electric, gas, water and sanitary services.....	97	205	1	2	40	41	69	172	74	44	61	9	53	633
69	Wholesale and retail trade.....	1,333	1,527	45	28	18	23	68	175	51	10	6,503	1,723	267	2,774
70	Finance and insurance.....	257	314	16	2	9	31	32	93	25	9	572	86	24	335
71	Real estate and rental.....	475	2,062	13	79	133	43	160	2,420	89	40	593	101	46	711
72	Hotels, personal and repair services except auto.....													15	162
73	Business services.....	76	1,231	(*)	(*)	62	22	81	242	75	31	4,382	329	263	3,101
74	Automobile repair and services.....	124	132		1	1	2	6	17	17	1	385		16	161
75	Amusements.....														
76	Medical, educational services and nonprofit organizations.....	183	17			1	1	2		(*)	1	84	13	16	45
77	Federal Government enterprises.....	3	4	(*)	(*)	1	1	2	6		2	28	4	13	62
78	State and local government enterprises.....											29	5	1	18
79A	Directly allocated imports.....														1,310
79B	Transferred imports.....	182	335	505	36	540	318	2	1,076	111	90			60	1,334
80	Exports.....	28	40	13	5	3	5	8	87	10	6			167	362
81	Other supplies.....	1	1	1	1	(*)	7	1	6	1	6			4	13
82	Scrap, used and secondhand goods.....							18	80		(*)				(*)
83	Government industry.....														
84	Rest of the world industry.....														
85	Household industry.....														
86	Inventory valuation adjustment.....														
87	Imports of inputs, total.....	22,552	14,587	1,126	1,146	1,238	1,029	1,319	6,420	1,061	430	48,033	9,652	5,874	65,474
88	Value added.....	8,096	13,933	810	1,524	500	611	1,844	8,511	1,321	597	31,856	13,719	4,850	53,403
89	Indirect compensation.....	1,811	4,169	118	718	187	423	1,237	482	733	180	23,096	11,763	4,097	33,152
90	Indirect business taxes.....	768	977	11	62	49	65	69	735	46	88	183	97	73	1,443
91	Property-type income.....	6,403	10,817	638	2,14	405	135	635	6,092	412	599	6,778	1,829	658	64,414
92	Total.....	39,638	28,510	1,945	2,670	1,744	1,640	3,163	15,031	2,353	1,027	79,883	23,391	10,733	89,431
93	Transfers.....	228	403	760	800	654	328	1,128		258	169			1,491	2,808

TABLE H-1 CONTINUED.

Tobacco manufactures	Broad and narrow fabrics, 3 am and third mills	Miscellaneous textile goods and floor coverings	Apparel	Miscellaneous fabricated textile products	Lumber and wood products, except containers	Wooden containers	Household furniture	Other furniture and fixtures	Paper and allied products, except containers	Paperboard containers and boxes	Printing and publishing	Chemicals and related chemical products	Plastics and synthetic materials	Drugs, cleaning, and toilet preparations	Paints and allied products	Petroleum refining and related industries	Rubber and miscellaneous plastic products	Leather tanning and industrial leather products	Footwear and other leather products	Indus- try p.
15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	
1,423	101 1,154	159 21	165		1,002							36 13	(*)	12	58 1			15		1
2	16	2	3	1	3	(*)	2	1	70	1	1	71 71 40 60 608	30	4	(*)	10 11,556 63	10	2	(*)	2
7	51	11	25	4	64	(*)	18	11	120	28	79	101 111 194	53	40	12	363	50 2	2	6	6
1	32	14	(*)	(*)	(*)	(*)	7	9	134	1	4	111	50	300	77	31	6	256	6	6
1,604	5,170 458 39 45 18 4	820 294 66 56 1	5,662 294 4,654 374	1,758 410 78 93 8	3,492 33 29 17	11	254 101 15 17 13	14 47 8 10 17	151 44 18 5	(*) 7 13	79	43 44 18 5	45 1 3 4	3	1	1	328 452 28	1	123 121 46 45	123 121 46 45
53	(*)	5	5	7	29	(*)	78	55	1,186	(*)	1	55	(*)	(*)	(*)	2	41	(*)	(*)	(*)
57	60	29	52	34	3	2	65	34	2,683	2,444	3,311	230	257	91	6	55	128	1	1	1
34	1	9	10	(*)	21	3	1	2	139	109	72	116	84	337	22	75	169	(*)	3	3
14	369	65	54	1	160	2	10	5	622	141	400	4,407	2,928	1,363	513	633	510	53	6	6
85	1,524	751	444	25	15	(*)	77	34	193	21	40	670	235	74	276	4	2,276	17	39	39
16	66	3	1	1	53	(*)	105	4	102	30	40	305	49	675	15	83	15	(*)	1	1
2	21	6	21	2	61	(*)	226	111	305	28	58	1,800	119	54	40	1,831	561	3	363	363
49	42	77	30	81	(*)	(*)	(*)	1	1	1	1	(*)	(*)	(*)	(*)	(*)	25	4	119	112
1	14	14	1	(*)	1	(*)	32	28	33	2	1	11	5	193	(*)	(*)	65	2	1	1
1	1	2	(*)	1	15	(*)	97	250	(*)	33	10	181	4	1	10	58	10	(*)	(*)	(*)
15	7	2	24	(*)	39	(*)	35	27	189	50	162	240	27	190	169	83	6	(*)	1	1
(*)	6	(*)	(*)	(*)	179	(*)	11	10	(*)	1	68	(*)	1	1	(*)	(*)	201	(*)	(*)	(*)
1	87	18	8	11	11	(*)	(*)	(*)	16	42	1	23	3	1	(*)	18	6	(*)	(*)	(*)
(*)	2	(*)	10	11	18	(*)	11	10	15	13	13	15	16	8	(*)	5	17	(*)	(*)	(*)
(*)	1	2	8	11	11	(*)	(*)	(*)	25	54	20	228	19	5	(*)	65	13	(*)	(*)	(*)
(*)	1	2	1	1	3	(*)	13	4	4	(*)	1	(*)	3	1	(*)	30	2	(*)	(*)	(*)
(*)	1	(*)	5	1	2	(*)	1	5	8	4	1	19	(*)	1	(*)	12	2	(*)	(*)	(*)
1	1	11	(*)	(*)	6	(*)	10	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	3	(*)	(*)	(*)
1	2	2	(*)	1	4	(*)	4	12	4	1	1	16	1	2	1	3	15	(*)	(*)	(*)
(*)	3	1	13	20	1	(*)	11	22	16	2	7	2	(*)	53	(*)	17	51	(*)	(*)	(*)
35	253	108	312	31	15	(*)	1	16	9	14	2	20	3	12	2	1	92	1	41	41
7	30	11	92	13	32	2	23	16	49	27	250	611	177	102	81	1,389	233	31	35	35
12	175	36	97	23	121	5	32	19	319	45	121	120	51	18	17	25	62	3	18	18
57	186	101	661	115	441	24	223	89	535	151	550	543	200	369	101	303	440	90	113	113
15	49	14	100	19	79	3	33	20	75	17	131	100	35	60	13	250	540	8	28	28
50	122	56	311	41	109	(*)	68	37	219	90	965	543	160	387	67	630	170	14	60	60
18	5	4	6	6	(*)	8	3	2	25	18	3	17	10	55	14	15	18	(*)	3	3
300	178	72	366	50	197	1	125	64	359	133	921	681	241	2,066	102	770	430	13	116	116
1	8	2	21	3	57	(*)	7	4	13	7	55	22	8	10	4	1	13	1	4	4
1	5	2	14	2	5	(*)	4	2	8	4	41	17	6	31	3	7	9	1	5	5
13	13	4	51	6	7	(*)	0	2	12	(*)	278	35	4	21	4	12	12	1	13	13
(*)	2	(*)	1	(*)	2	(*)	(*)	(*)	4	(*)	3	8	1	1	(*)	1	101	1	8	8
8	29	24	9	(*)	758	(*)	31	31	1,306	17	19	637	154	114	26	1,018	197	70	13	13
14	340	381	50	15	34	(*)	3	3	11	5	201	130	70	105	45	27	130	3	23	23
41	46	112	114	3	7	(*)	36	5	239	(*)	(*)	33	4	10	4	11	11	1	7	7
2	11	2	22	16	3	(*)	4	5	(*)	(*)	(*)	33	(*)	(*)	30	11	18	(*)	(*)	(*)
1	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)
4,060	11,155	14,216	3,081	8,075	2,314	2,860	1,588	2,312	1,773	10,540	3,813	11,157	10,991	7,761	1,971	20,785	7,134	718	2,416	2,416
3,260	4,611	1,229	8,319	1,219	4,805	2,312	1,773	1,074	915	6,197	2,318	10,991	10,991	4,832	915	6,197	2,318	1,074	915	915
2,151	3,345	798	8,066	948	3,081	1,588	2,312	1,074	915	6,197	2,318	10,991	10,991	4,832	915	6,197	2,318	1,074	915	915
1,105	1,319	413	1,117	359	1,631	851	382	1,105	1,319	413	1,117	359	1,631	851	382	1,105	1,319	413	1,117	359
7,940	15,166	4,666	22,566	4,293	12,905	8,122	2,822	16,733	6,031	22,118	21,182	8,421	12,652	2,914	26,975	13,809	1,090	4,210	4,210	4,210
14	153	705	168	666	1,819	30	188	281	1,770	188	281	3,955	1,652	894	100	1,969	1,073	91	112	112

TABLE H-1 CONTINUED.

Industry No.	For the distribution of output of an industry, read the row for that industry. For the composition of inputs to an industry, read the column for that industry.	Industry															
		Glass and glass products	Stone and clay products	Primary iron and steel manufacturing	Primary nonferrous metals manufacturing	Metal containers	Heating, plumbing, and electrical products	Stamplings, screw machine products and bolts	Other fabricated metal products	Engines and turbines	Farm machinery and equipment	Construction, mining and oil field machinery	Machinery and equipment	Metalworking machinery and equipment	Special machinery and equipment		
		35	36	37	38	39	40	41	42	43	44	45	46	47	48		
1	Livestock and livestock products.....																
2	Other agricultural products.....																
3	Forestry and fishery products.....																
4	Agricultural, forestry, and fishery services.....																
5	Iron and ferrous alloy ores mining.....		10	1,497	5				1								
6	Nonferrous metal ores mining.....		12	57	1,052												
7	Coal mining.....	2	56	644	12	(*)	1	3	3	2	3	2	1	1	1		
8	Crude petroleum and natural gas.....																
9	Stone and clay mining and quarrying.....	43	707	65	4		1		2								
10	Chemical and fertilizer mineral mining.....	4	42	20	3				7								
11	New construction.....																
12	Maintenance and repair construction.....	32	99	291	70	(*)	2	40	26	38	12	13	22	6	24	18	
13	Ordinance and accessories.....				(*)	(*)		12	15	24	4	7	1	1	2	13	
14	Food and kindred products.....		6	1	8	1		1									
15	Tobacco manufactures.....																
16	Broad and narrow fabrics, yarn and thread mills.....		40		10												
17	Miscellaneous textile goods and floor coverings.....		24		1		(*)		24								
18	Apparel.....		5	9	21		10	8	11								
19	Miscellaneous fabricated textile products.....																
20	Lumber and wood products, except containers.....	33	32	74	76	(*)	20	20	43	(*)	2	3	4	2	7	4	
21	Wooden containers.....		5	5	10		9	9	3								
22	Household furniture.....	17	(*)				2	2	12	1		(*)			(*)	(*)	
23	Other furniture and fixtures.....	(*)	(*)		(*)		31	2	15								
24	Paper and allied products, except containers.....	28	197	9	37		8	25	63								
25	Paperboard containers and boxes.....	108	66	18	18		45	54	126	13							
26	Printing and publishing.....	1	1	3	137		2	2	1	(*)	2						
27	Chemicals and selected chemical products.....	83	205	392	194	5	14	20	138								
28	Plastics and synthetic materials.....		68	(*)	165		17	1	1								
29	Drugs, cleaning and toilet preparations.....		4		2	3	9	4	8								
30	Paints and allied products.....	19	8	14	11	91	102	21	69	4		12	11	3	13	2	
31	Petroleum refuse and related industries.....	7	104	116	48	3	38	17	44	15		11	20	6	42	26	
32	Rubber and miscellaneous plastics products.....	92	122	33	50	5	25	210	8	130		31	31	1	72	45	
33	Leather and other leather products.....		3		6			2	2			(*)	(*)	(*)	1	1	
34	Footwear and other leather products.....		(*)		(*)		(*)	1	2			(*)	(*)	(*)	1	1	
35	Glass and glass products.....	242	3	2	1		65	4	19						(*)	2	
36	Stone and clay products.....	64	1,231	113	40	10	38	22	57	33		42	8	85	4	2	
37	Primary iron and steel manufacturing.....	126	6,017	340	1,238	3,018	2,268	2,200	364	655	951	268	675	675	675	675	
38	Primary nonferrous metal manufacturing.....	28	12	859	6,723	130	674	872	105	82	89	83	231	159	159	159	
39	Metal containers.....																
40	Heating, plumbing, and electrical products.....		11	68	2	2	268	22	4								
41	Stamplings, screw machine products and bolts.....		1	210	46	60	278	126	210	74	105	51	33	30	30	30	
42	Other fabricated metal products.....		3	114	455	184	339	116	412	43	72	72	67	169	47	47	
43	Engines and turbines.....			6	6		29	10	13	283	294	129	32	8	33	33	
44	Farm machinery and equipment.....		(*)	33	1		8	11	25	228	64	20	8	14	14	14	
45	Construction, mining and oil field machinery.....		71	18	1		42	1	21	143	161	101	19	20	20	20	
46	Metalworking machinery and equipment.....		12	81	297	168	7	64	169	187	49	38	119	38	612	134	
47	Metalworking machinery and equipment.....		11	35	2	4	21	10	31	13	9	10	9	47	284	4	
48	Special industry machinery and equipment.....		31	344	89	1	131	14	93	139	319	369	149	220	230	230	
49	General industrial machinery and equipment.....		11	205	103	(*)	119	73	100	42	38	60	70	70	70	70	
50	Machine shop products.....																
51	Office, computing and accounting machines.....		(*)		(*)		164	16	1								
52	Service industry machines.....		1	14	289	126	(*)	128	6	81	24	74	91	253	203	203	
53	Electric industrial equipment and apparatus.....		(*)	4			36	15	6								
54	Household appliances.....		(*)	6	23	19	22	1	8	24	28	(*)	1	1	1	1	
55	Electric lighting and wiring equipment.....		(*)	2	4	13	(*)	3	2								
56	Radio, television and communication equipment.....		(*)	(*)	(*)	(*)	(*)	2	2	6	(*)	1	1	1	1	1	
57	Electronic components and accessories.....		(*)	(*)	(*)	(*)	(*)	2	2	1	(*)	10	1	1	1	1	
58	Miscellaneous electrical machinery, equipment and supplies.....		(*)	(*)	103	(*)	(*)	1	74	40	10	5	2	2	2	2	
59	Motor vehicles and equipment.....		14	121	46	(*)	51	228	74	89	31	65	28	78	78	78	
60	Aircraft and parts.....			1	1	4	51	7	11	161	1	24	8	21	21	21	
61	Other transportation equipment.....			12	(*)	1	47	3	8	35	7	29	2	(*)	6	6	
62	Scientific and controlling instruments.....		7	5	6	1	67	20	34	(*)	6	14	33	12	14	14	
63	Optical, photographic and photoduplicating equipment.....		1	1	(*)		2	3	3			(*)	3	2	10	4	
64	Miscellaneous manufacturing.....		7	41	17		21	20	20								
65	Transportation and warehousing.....	108	650	1,420	539	71	201	142	142	32	65	59	20	59	45	45	
66	Communications, except radio and TV broadcasting.....	13	57	95	44	6	75	35	58	16	18	30	17	47	34	34	
67	Radio and TV broadcasting.....																
68	Electric, gas, water and sanitary services.....	138	358	822	427	25	66	62	121	19	24	10	11	58	27	27	
69	Wholesale and retail trade.....	118	200	934	746	33	409	179	300	129	7	201	79	267	206	206	
70	Finance and insurance.....	20	90	182	116	15	91	41	65	7	37	34	13	35	35	35	
71	Real estate and rental.....	72	208	80	153	32	173	53	149	28	46	81	39	129	178	178	
72	Hotels, personal and repair services except auto.....	4	7	14	3	2	43	5	12	3	6	5	2	8	3	3	
73	Business services.....	111	283	841	279	83	243	147	277	53	143	117	63	161	90	90	
74	Automobile repair and services.....		33	27	11	2	16	6	13	4	5	7	3	9	7	7	
75	Amusements.....																
76	Medical, dental, and other health and nonprofit organizations.....		3	10	11	1	10	6	9	2	3	5	5	5	5	5	
77	Federal Government enterprises.....		4	10	9	1	11	6	11	3	5	6	3	8	8	8	
78	State and local government enterprises.....		(*)	8	3	(*)	(*)	1	1	1	(*)	(*)	(*)	(*)	(*)	(*)	
79	Directly allocated imports.....				63												
80A	Transferred imports.....	85	176	1,420	1,984	8	34	114	293	57	1	83	22	275	260	260	
81	Business travel, entertainment and gifts.....	25	68	88	52	87	133	53	83	31	30	17	81	6	6	6	
82	Other supplies.....	4	10	19	8	1	11	4	10	3	4	5	2	7	7	7	
83	Corp. used and secondhand goods.....	8	3	841	871		32	4	16	9	9	3		8	14	14	
84	Government industry.....																
85	Rest of the world industry.....																
86	Household industry.....																
87	Inventory valuation adjustment.....																
88	Intermediate inputs, total.....	1,622	6,022	10,336	15,156	2,185	7,902	5,001	7,002	2,457	3,140	8,448	1,338	4,307	3,285	3,285	
V. 1.	Value added.....	2,102	5,025	12,587	8,715	1,170	4,601	4,262	5,517	2,457	3,140	8,448	1,338	4,307	3,285	3,285	
F. C.	Federal Government enterprises.....	1,414	3,381	5,176	3,453	763	3,435	3,079	3,618	1,001	1,149	1,747	789	5,291	1,897	1,897	
I. B. T.	Indirect business taxes.....	33	145	388	168	31	86	18	85	27	33	65	18	78	57	57	
P. T. I.	Properly type income.....	668	1,619	4,861	1,106	387	1,079	1,108	1,806	317	403	713	1,003	1,003	1,003	1,003	
T.	Total.....	8,801	11,026	31,725	25,878	3,358	12,816	9,293	12,819	3,825	4,826	11,774	2,638	8,676	8,676	8,676	
T. 1.	Transfers.....	199	671	4,532	2,684	80	1,019	748	2,090	688	428	476	303	1,800	776	776	

TABLE H-1 CONTINUED.

General industrial machinery and equipment	Machine shop products	Office computing and accounting machines	Service industry machines	Electric industrial machinery and apparatus	Household appliances	Electric lighting and wiring equipment	Radio, television and communication equipment	Electronic components and accessories	Miscellaneous electrical equipment and supplies	Motor vehicles and equipment	Aircraft and parts	Other transportation equipment	Scientific and controlling instruments	Optical, photomicrographic and photographic equipment	Miscellaneous manufacturing	Transportation and warehousing	Communications, TV, broadcasting	Radio and TV broadcasting	Electric, gas, water and sanitary services	Industry No.
49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	
2	1	1	1	3	2	1	2	1	7	16	7	2	(*)	3	2	41	(*)	(*)	(*)	1
27	10	15	15	32	17	11	46	28	8	105	65	22	18	20	23	1,307	587	6	1,137	1
4	2	1	1	19	(*)	6	101	37	(*)	29	406	23	21	1	17	168			(*)	2
(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	2
21	2	2	2	13	4	4	11	5	8	137	21	(*)	75	2	141	35	5		(*)	2
3	3	3	3	3	3	3	3	3	3	18	14	40	18	3	21	19	2		(*)	7
5	3	3	3	3	3	3	3	3	3	598	3	299	9	1	148	35	5		(*)	8
14	15	15	15	24	9	9	24	29	24	43	3	30	10	(*)	3	42	27		(*)	1
13	7	2	2	9	13	23	33	109	73	55	15	15	10	84	27	36	50		(*)	3
1	1	1	1	1	1	1	1	1	1	61	14	2	20	208	63	40	5		(*)	2
30	30	30	30	30	30	30	30	30	30	24	26	21	25	219	15	5	1		(*)	3
41	41	41	41	41	41	41	41	41	41	153	16	22	53	4	33	1,992	65		(*)	2
1	1	1	1	1	1	1	1	1	1	353	1	1	12	48	39	41	1		(*)	3
85	85	85	85	85	85	85	85	85	85	31	41	23	35	12	33	261	10		(*)	1
36	36	36	36	36	36	36	36	36	36	1,073	432	890	166	20	246	66	10		(*)	11
126	8	21	124	161	24	18	7	7	8	3	8	281	10	(*)	6	3			(*)	39
50	50	50	50	50	50	50	50	50	50	2,498	395	53	113	53	87	10	1		(*)	40
145	8	8	8	8	8	8	8	8	8	1,220	352	153	129	73	180	200	1		(*)	1
73	2	2	2	2	2	2	2	2	2	221	63	284	8	(*)	12	6			(*)	2
58	3	3	3	3	3	3	3	3	3	63	4	31	8	(*)	4	2			(*)	41
20	1	1	1	1	1	1	1	1	1	22	5	5	69	3	4	6			(*)	46
156	101	75	18	134	(*)	20	105	69	(*)	402	337	83	69	3	4	39	1		(*)	47
57	57	57	57	57	57	57	57	57	57	4	4	4	4	4	4	4	4		(*)	48
65	217	34	79	70	52	8	16	3	38	207	177	285	30	31	12	4	135		(*)	49
(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	439	662	36	30	5	7	14	(*)	(*)	(*)	50
49	1	1	1	1	1	1	1	1	1	1	6	(*)	10	15	1	4	4		(*)	51
153	24	145	410	735	3	287	257	157	64	145	78	84	163	37	40	39	6		(*)	52
(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	157	33	77	25	34	35	6	10		(*)	53
3	1	1	1	1	1	1	1	1	1	149	618	1	143	26	20	1	213		(*)	54
4	50	(*)	730	1	257	19	1,141	16	13	35	146	2	157	82	28	3	20	10	(*)	55
41	41	41	41	41	41	41	41	41	41	521	68	9	21	5	4	46	2		(*)	56
01	27	2	2	2	2	2	2	2	2	12,157	38	143	46	16	16	71	3		(*)	59
18	2	2	2	2	2	2	2	2	2	49	65	14	47	5	13	313			(*)	60
20	1	1	1	1	1	1	1	1	1	27	140	6	1	18	403				(*)	61
1	(*)	15	69	113	145	5	55	11	14	101	317	13	459	8	14	42			(*)	62
71	1	1	1	1	1	1	1	1	1	10	1	1	78	300	1	2			(*)	63
16	28	29	40	80	38	3	31	4	1	10	16	36	12	58	16	4			(*)	64
20	42	23	23	63	20	20	144	61	24	710	97	121	38	34	135	5,228	41		(*)	65
51	41	10	24	68	47	37	77	61	95	108	40	32	21	49	342	135	4		(*)	66
227	188	216	325	179	129	490	200	101	920	442	309	230	141	421	1,027	144	55		(*)	67
31	19	140	304	18	53	39	19	10	30	19	73	33	29	50	76	14	219		(*)	68
101	118	255	61	198	81	228	189	51	192	310	88	100	78	151	1,360	353	146		(*)	69
160	62	119	120	331	103	478	217	71	63	25	61	5	8	6	60	212	57		(*)	70
10	4	7	5	13	4	5	31	10	3	659	39	6	8	4	9	795	101		(*)	71
(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	11	27	5	10	5	10	19	812		(*)	72
(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	(*)	4	3	(*)	8	(*)	(*)	1,405	80		(*)	73
107	1	168	13	169	10	60	677	151	94	595	160	170	142	183	440	1,363	131		(*)	74
86	49	157	54	113	4	40	151	129	20	118	270	61	103	38	25	348	79		(*)	75
2	3	7		8	3	3	22	8	9	21	21	7	5	9	13	7	3		(*)	76
10							(*)	(*)	(*)	212	(*)	(*)	(*)	(*)	(*)	6			(*)	77
1,339	1,756	3,702	3,046	5,361	3,507	2,151	3,518	4,504	1,830	30,312	12,131	4,923	3,507	2,008	5,560	21,822	8,290	1,011	19,609	1
3	3	2,701	1,073	4,533	1,913	1,921	7,512	3,043	1,903	14,438	9,472	2,889	2,025	2,637	3,771	30,976	10,29	1,880	17,712	V.A.
4,470	1,046	2,060	1,161	3,337	1,343	1,600	6,511	5,119	973	8,435	8,676	2,490	1,939	4,419	2,719	20,929	6,494	1,000	4,001	42.0
61	87	35	24	73	31	27	96	10	21	1,916	231	63	62	23	63	1,809	2,404	187	8,111	14.4
331	610	710	1,138	861	658	1,107	477	369	219	2,949	1,666	146	629	1,211	984	4,528	7,167	157	10,659	14.4
7,800	3,940	6,532	5,279	9,903	6,450	4,118	17,331	8,147	1,346	43,749	21,993	7,811	6,191	4,779	9,357	62,823	19,328	3,183	37,373	77.0
1,073	185	767	1,018	1,087	229	356	1,820	810	125	1,364	958	441	487	376	1,060	5,774	1	2,547	2,547	77.0



TABLE H-1 CONTINUED.

Industry No.	For the distribution of output of an industry, read the row for that industry. For the composition of inputs to an industry, read the column for that industry.	Wholesale and retail trade	Finance and insurance	Real estate and rental	Hotels, personal and repair services except auto	Business services	Automobile repair and services	Amusements	Medical, educational services and nonprofit organizations	Federal Government enterprises	State and local government enterprises	Other imports of goods and services	Business travel, entertainment and gifts	Office supplies	Scrap, used and second-hand goods	
		69	70	71	72	73	74	75	76	77	78	79	80A & 80B	81	82	83
1	Livestock and livestock products			1,127					52							
2	Other agricultural products	10		1,200	7				203							
3	Forestry and fishery products			2					(*)							
4	Agricultural, forestry and fishery services	139		159					25							
5	Iron and ferroalloy ores mining	(*)		4												
6	Nonferrous metal ores mining	1		10												
7	Coal mining	3	1	37	6	1	(*)	(*)								
8	Crude petroleum and natural gas			165												
9	Stone and clay mining and quarrying	5		28												
10	Chemical and fertilizer industrial mining			6												
11	New construction															
12	Maintenance and repair construction	526	135	188	259	33	101		739	60	1,711					
13	Food and kindred products	892		134					502	121						
14	Tobacco in leaf and cut	9		2												
15	Textile mill and textile products	20		22												
16	Wool and woven fabrics, yarn and thread mills	20		21												
17	Miscellaneous textile goods and floor coverings	53		12	9	(*)			(*)	1						
18	Apparel	131		51					33							
19	Miscellaneous made-up textile products	3		183	(*)				22	14						
20	Lumber and wood products, except containers	92		23	11											
21	Wooden containers	107		1												
22	Household furniture	24		7												
23	Other furniture and fixtures	28		4												
24	Paper and allied products except containers	1,041	251	41	105	101	5	8	94	8	10					
25	Printing and publishing	379	415	126	13	0,361	(*)		21	673	26					
26	Chemicals and selected chemical products	215	1	301	63	149	4	39	54	5	122					
27	Plastics and synthetic materials	23		30												
28	Drugs, chemical and toilet preparations	274		101	473	101	7	1	1,140	17	21					
29	Paints and allied products	17		15	17	37			1	(*)						
30	Rubber and related products	1,375	62	220	23	131		15	219	45	68					
31	Rubber and miscellaneous plastics products	711	14	134	197	405	233	3	150	13	28					
32	Leather tanning and industrial leather products	2		1		14										
33	Footwear and other leather products	39		6	201											
34	Glass and glass products	139		18	5	27	100		5		2					
35	Stone and clay products	153		63	76	94	3		12	(*)	3					
36	Primary iron and steel manufacturing	42		37	7					(*)	8					
37	Primary nonferrous metal manufacturing	107		8	4	36										
38	Metal containers	180		45												
39	Heating, plumbing and structural metal products	62		13	60	305	949		9	4						
40	Stamplings, screw machine products and bolts	154		22	139	255	165			1						
41	Other fabricated metal products	17		4	28	15										
42	Trucks and trailers	34		103		56				(*)	13					
43	Construction, mining and oil field machinery	50		37	301					(*)	1					
44	Materials handling machinery and equipment	32		16												
45	Metalworking machinery and equipment	68		24	10	29	2		5	(*)	1					
46	Special industry machinery and equipment	60		139												
47	General industrial machinery and equipment	69		22		90										
48	Metal shop product	35		23	131	310										
49	Other, computing and accounting machines	83		247		156										
50	Service industry machines	49		9	157	67	4			(*)	2					
51	Electric industrial equipment and apparatus	55		64	29	129	4	1								
52	Household appliances	82		25	125	11	25									
53	Electric lighting and wiring equipment	65	3	28	19	1	25	3	29	1	13					
54	Radio, television and communication equipment	78		3						(*)						
55	Electronic components and accessories	71		34	339	14	3			(*)						
56	Miscellaneous electrical machinery, equipment and supplies	95	2	11	7	9	243	(*)	5							
57	Motor vehicles and equipment	99		116	5	39	1,259									
58	Aircraft and parts	68		32		(*)			1							
59	Other transportation equipment	11		11												
60	Scientific and controlling instruments	109		32	18	28	5		289	(*)	4					
61	Optical, photographic and photographic equipment	121	2	30	163	263	4	83	163	1						
62	Miscellaneous manufacturing	210	2	35	361	524	4	34	181	1						
63	Transportation and warehousing	1,235	115	1,096	144	331	113	78	21	1,137	115					
64	Communications, except radio and TV broadcasting	1,769	973	212	170	1,279	89	67	574	20						
65	Radio and TV	2,415	392	438	367	201	84	89	149	136						
66	Electric, gas, water and sanitary services	3,382	98	1,612	669	1,090	1,469	200	951	78	110					
67	Wholesale and retail trade	2,474	8,701	3,574	398	365	203	108	389	87	173					
68	Finance and insurance	8,669	1,931	3,054	1,441	2,149	192	716	2,761	186	161					
69	Real estate and rental	577	3,167	3,169	532	315	14	27	1,262	192	348					
70	Hotels, personal and repair services except auto	8,460	3,169	3,169	532	315	14	27	1,262	192	348					
71	Automobile repair and services	1,761	144	167	337	505	26	31	337	43	39					
72	Amusements	181	3	207	2	173		1,658	31	6						
73	Medical, educational services and nonprofit organizations	230	502	85	64	118	8	22	664	1	13					
74	Federal Government enterprises	1,701	851	411	35	594	7	41	353	2	13					
75	State and local government enterprises	940	128	923	11	9	155	2	30		6					
76	Direct, all other imports	46	81			6			2	2	343					
77	Transit and express	20														
78	Business travel, entertainment and gifts	2,015	807	105	299	1,151	69	224	780	28	48					
79	Office supplies	340	610	54	31	184	6	14	160	6	15					
80	Scrap, used and second-hand goods	10	1	(*)	(*)	(*)	38	(*)	1		(*)					
81	Government industry															
82	Rest of the industry															
83	Household industry															
84	Inventory valuation adjustment															
85	Intermediate inputs, total	45,161	20,853	29,181	8,393	27,369	6,656	4,624	14,610	3,075	4,465					
86	Value added	118,265	28,820	81,053	12,412	29,076	8,101	5,020	33,877	4,616	5,242					
87	Factor cost compensation	62,414	18,374	44,040	7,056	16,036	3,745	2,574	15,456	5,248	6,070					
88	Indirect taxes, total	22,829	1,913	18,913	480	413	605	356	116	67						
89	Property-type income	25,665	4,616	63,259	6,037	10,116	4,110	1,499	10,116	-1,531	5,172					
90	Total	163,385	47,752	111,253	20,805	56,444	14,768	9,444	45,567	7,691	9,647					
91	Transfers	6,717	188	11,896	1	15,743	147	69								

TABLE H-1 CONTINUED.

Government industry	Rest of the world industry	Household industry	Inventory valuation adjustment	Intermediate outputs, total	Final Demand										Total final demand	Total	Transfers <sup>1</sup>	Industry No.	
					Personal consumption expenditures	Gross private fixed capital formation	Net inventory change	Net exports <sup>2</sup>	Federal Government Purchases			State & Local Government Purchases							
									Total	Defense	Nondefense	Total	Education	Other					
84	85	86	87																
				28,620	1,811		129	55	8	5	4	15	1	13	2,018	30,633	2,433	1	
				21,691	4,754		1,031	8	-1,106	7	-1,202	72	16	37	6,819	28,510	2,182	2	
				1,696	49		2	47	255	6	200	5	1	6	249	1,945	52	3	
				2,486	136			14	31	10	1	24	17	7	185	2,670	14	4	
				1,662			25	122	-65	-65	(*)				82	1,744	10	5	
				1,407			12	35	125	58	67				173	1,610	36	6	
				2,545	121		257	300	43	36		22	15	7	616	3,163	42	7	
				14,692			82	84			-1	-47		-47	339	15,031	1,138	8	
				2,304	4		12	149	-2	-1	-1	-17		-17	51	2,355	93	9	
				838	2	54,338	8	149		(*)	(*)	31		31	169	1,027	237	10	
				17,694			15	309	3,475	975	2,501	22,061	6,176	15,885	79,889	79,889		11	
				1,657	322	25	147	309	1,453	973	480	4,241	772	3,470	5,095	23,321		12	
				24,540	60,974		1,000	1,000	8,268	6,432	1,834	477	68	409	64,911	89,431		13	
				1,881	5,770		189	601				-1		-1	6,050	7,980		14	
				14,908	592		114	250		73	1	27	9	18	1,008	15,968	980	15	
				2,958	1,400	89	107	89		14	0	(*)	(*)		1,710	4,668	282	16	
				5,693	16,247		281	169		20	0			41	16,867	22,564	280	17	
				1,824	1,983		49	74	127	56	31	17	2	12	2,459	14,283	171	18	
				12,118	559	7	121	387	325	325	13	43	3	1	787	14,908	284	19	
				513			3	3	24	21	3	28		8	39	547	43	20	
				939	3,881	165	49	24	56	20	31	237	21	8	4,183	5,122	182	21	
				570	174	1,632	41	19	87	40	50	297	235	62	2,251	7,822	178	22	
				14,069	1,502		228	649	116	62	55	170	13	85	2,673	16,731	1,251	23	
				5,841	73		30	34	34	29	5	91	12	9	5,075	10,731		24	
				16,358	4,119		297	252		180	49	864	720	144	5,740	22,118	11,338	25	
				18,797	504		305	1,710	1,752	1,252	466	113	15	19	4,358	20,181	1,674	26	
				7,644	18		26	670	65	65	(*)	1	(*)	(*)	779	8,421	980	27	
				3,913	7,294		221	435	192	121	71	537	145	383	8,679	12,582	872	28	
				2,754			54	52	3	3	3	3	2	1	1,308	2,944	195	29	
				14,105	10,194		541	765	1,078	039	139	292	148	148	12,878	26,975	2,018	30	
				10,481	2,309	30	142	323	362	355	37	172	45	128	3,323	13,409	823	31	
				1,047			-6	43	6	5	2				43	1,049	27	32	
				522	3,659		21	20	16	14	2	3	3	3	3,714	4,210	131	33	
				3,225	317		39	145	18	10	8	53	22	31	573	3,801	69	34	
				10,438	244		127	177	26	23	4	13	9		288	11,023	312	35	
				39,395	4		514	519	260	288	4	2		2	1,398	31,723	2,018	36	
				19,732	15	34	336	725	8	42	-34	(*)	(*)		1,119	9,570	1,103	37	
				3,255			61	16	13	13	43				100	3,355	322	38	
				10,878	60	933	128	281	222	179	43				1,633	12,510	604	40	
				8,403	374		86	274	139	108	31	13	23	-10	846	9,239	843	41	
				10,479	774		168	435	263	226	37	33	27	9	2,039	12,519	976	42	
				2,073	144		155	735	495	366	49	9	9	61	1,754	5,435	410	43	
				1,834	38	2,428	409	419	29	25	4	30	9	21	3,868	4,355	367	44	
				1,163		2,428	58	1,270	307	295	13	57		57	4,100	5,971	737	45	
				4,300	88		107	486	152	116	36	23	14	9	1,376	2,435	223	46	
				1,516	22		107	791	46	37	14	12	11	1	4,356	8,679	582	47	
				4,811	13	1,883	125	627	363	243	13	2	1	1	2,466	7,403	568	48	
				3,665	4		62	107	18	0	15	108	17	336	2,910	284	49	50	
				1,659	111	3,352	150	710	533	243	291	169	119	42	5	6,481	6,481	521	51
				2,433	491		126	359	103	96	7	136	105	20	2,847	5,293	478	52	
				5,430	28	2,880	126	558	799	679	110	71	18	39	4,474	9,908	809	53	
				1,494	3,538	127	103	149	14	11	3	25	13	12	3,956	5,120	914	54	
				3,153	557	67	58	109	48	35	13	67	55	12	1,965	4,118	400	55	
				3,610	2,907	640	589	589	5,827	5,179	657	122	93	29	13,722	17,311	1,438	56	
				6,712	171	18	139	472	730	617	103	14	4	10	1,435	8,147	850	57	
				1,855	210		131	162	223	196	27	26	4	22	1,261	4,139	423	58	
				15,464	15,822	0,054	-310	1,976	1,092	847	155	731		182	510	28,256	43,710	1,671	59
				7,129	50	2,307	1,918	1,829	8,619	7,840	810	2			2	14,711	21,944	1,782	60
				1,386	1,078	3,450	193	297	1,517	1,227	220	18			18	6,455	2,811	428	61
				2,909	601	1,131	109	568	718	586	133	151	25	130	3,342	6,191	677	62	
				1,853	1,030	920	78	322	430	356	74	146	85	81	2,926	4,722	612	63	
				3,665	4,417	533	147	342	98	59	40	164	142	23	5,692	9,457	1,368	64	
				32,172	11,394	829	228	3,891	3,324	2,998	329	985	683	333	20,633	52,823	6,738	65	
				1,237	7,847	1,030		140	541	408	138	475	130	310	10,091	19,478	688	66	
				3,170				74	311	205	49	1,599	1,054	515	15,952	37,331	188	67	
				41,551	109,367	6,544	508	2,015	1,397	1,142	255	381	-38	472	130,815	103,365	3,431	68	
				21,044	25,267	4	-1	50	54	17	37	613	173	291	28,818	47,711	1,772	69	
				38,798	70,668	2,100		577	292	129	163	408	108	490	74,456	111,593		70	
				4,640	15,472			3	616	511	105	74	-139	24	16,165	30,908	2,197	71	
				47,156	4,609		458		1,860	1,660	824	1,521	631	920	9,290	54,411	909	72	
				6,473	8,009			61	35	35	9	152	43	110	8,365	14,776	89	73	
				3,587	5,571		-57	332	189	198	-7	23	21	-1	6,037	9,611	553	74	
				2,688	41,112				2,227	1,085	1,142	2,460	138		2,312	45,819	48,507	141	75
				5,810	1,221		100		281	225	57	390	27	280	1,811	7,694	1,066	76	
				8,414	935				298	298	298	11		9	1,553	9,645	7,061	77	
				2,826	0,670	658	-100												

TABLE H-2

ECASTAR INDUSTRY GROUP	COMMERCE DEPARTMENT INDUSTRY NO.
1	1,2,3,4
2	5,6
3	7
4	8
5	9,10
6	11,12
7	13
8	14,15
9	16,17,18,19
10	20,21,22,23
11	24,25,26
12	27,28,29,30
13	31
14	32,33,34
15	35,36
16	37,38
17	39,40,41,42
18	43,44,45,46,47,48,49,50,51,52,53
19	54
20	55
21	56,57,58
22	59,60,61
23	62,63,64
24	65
25	66
26	68.1
27	68.2
28	68.3
29	69
30	70-79

I-1

## APPENDIX I. NATIONAL ENERGY CONSERVATION DATA

This appendix presents data mentioned in Chapter 9. Also, an elaboration on some of the National Energy Conservation actions of Chapter 9 are contained herein.

### I.1 ACTIONS 1 AND 3 TABLES AND FIGURES

The Tables I.1-1 through -6 plus Figure I. 1-1 refer back to Action 1 of Chapter 9. Tables I.1-7 through -10 and Figure I.1-2 are referenced to Action 3.

#### The Petroleum Industry Economic Viewpoint

Petroleum industry projected capital requirements are expected to be increased 100-200% over the next decade if needed exploration and development activity is to take place. Deep inshore basins, Outer Continental Shelf, the Arctic and tertiary recovery are the areas of most intense activity, and these are high recovery cost areas. Inflation is another expenditure determinant. Financial capability of the private sector is the concern. Returns of 15-20% will be necessary to finance future capital needs, and since industry debt-equity ratios are about 30% since the 1960's, much of the capital must be generated from within. The industry maintains with some logic that the high profits of 1974 were not those of a typical year. Early 1975 earnings reports suggest profits were down to the 14-15% range. The industry suggests that further price regulation (as opposed to decontrol of prices) is a limit to financing needed resource development. Tables I.1-5 and I.1-6 from a statement before the Senate Committee on Finance by William T. Slick, Jr. display the capital requirements projected and the physical facility projections. These compare to FEA figures in Chapter 9 and Tables I.1-3 and I.1-4.

### I.2 ACTION 6 -- CONVERSION FROM OIL OR GAS TO OTHER FUELS

Action 6 provides mandatory and administrative measures to bring about a reduction in usage of scarce fuels through a policy of substitution. Because of recent and anticipated shortages of natural gas, a priority is established to convert electric utilities and large industrial users to alternate fuels. Oil is given a lower priority because supplies are currently sufficient (with imports included) but provisions are made to bring about a rapid conversion to coal or nuclear fuels. Both nuclear fuels and coal are relatively abundant and are available internally so that ultimate conversion to these is seen as a means of ultimate energy independence.

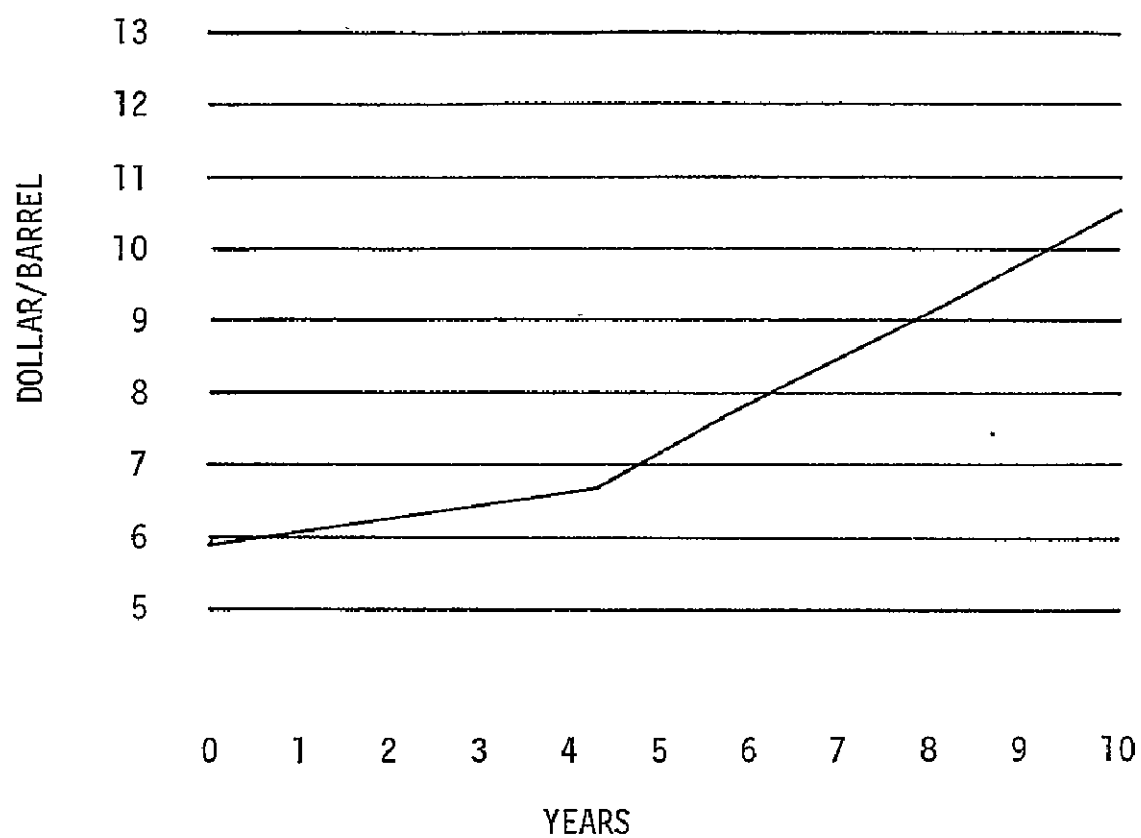


FIGURE I.1-1. COMBINED PRICE OF DOMESTIC OIL AS  
STATED IN THE PROPOSAL FOR PRICING

TABLE I.1-1. UNITED STATES UNCONSTRAINED REGIONAL PRODUCTION POSSIBILITIES FOR

CRUDE OIL, NATURAL GAS LIQUIDS\*\*, HEAVY CRUDES, AND TAR SANDS  
(Thousands of barrels per day at minimum acceptable prices\*) [PI-74-2, IV-3]

A. Business-As-Usual Alternative

Region or source	1974			1977			1980			1985			1988		
	\$4	\$7	\$11	\$4	\$7	\$11	\$4	\$7	\$11	\$4	\$7	\$11	\$4	\$7	\$11
Prudhoe	0	0	0	158	158	158	1600	1600	1600	1600	1600	1600	1466	1466	1466
N. Slope	0	0	0	0	0	0	0	434	434	0	900	900	0	863	863
1	201	201	201	158	190	190	120	243	243	59	468	468	38	719	719
2	792	792	792	674	732	758	590	635	796	498	527	970	449	471	929
2A	58	58	58	85	85	85	221	221	221	535	535	539	493	722	726
3	215	215	215	195	195	230	166	166	231	132	132	248	115	115	269
4	613	613	613	482	482	549	400	400	556	293	293	591	235	235	607
5	2554	2554	2554	2076	2131	2328	1778	1816	2331	1413	1437	2643	1180	1196	2801
6	3525	3525	3525	2731	2958	2958	2360	2759	2846	2198	2832	3311	2219	2852	3747
6A	1311	1311	1311	1367	1367	1367	1564	1564	1564	2056	2056	2056	2292	2292	2292
7	993	993	993	903	989	989	820	937	971	701	757	984	615	653	977
8-10	213	213	213	214	235	239	207	255	268	189	246	330	175	223	370
11	7	7	7	5	5	8	3	3	15	1	1	33	1	1	47
11A	0	0	0	0	0	0	0	0	0	40	40	40	60	110	110
Tar sands	0	0	0	0	0	0	0	25	25	0	100	100	0	200	200
Heavy Cr.	0	0	0	0	0	66	0	0	110	0	0	240	0	0	240
Total	10482	10482	10482	9048	9527	9925	9829	11058	12211	9715	11924	15053	9338	12118	16363

\* Includes exploration and production costs at regional wellheads plus royalty and 10 percent DCF on investment but excludes lease acquisition costs and rentals.

\*\* Includes pentanes plus and LPG from associated-dissolved gas and pentanes plus, LPG, and condensate from non-associated gas.

TABLE I.1-2

## SELECTED FORECASTS OF U.S. CRUDE OIL PRODUCTION [PI-74-2, II-16]

(Million Barrels per Day)

<u>Source</u>	<u>1975</u>	<u>1980</u>	<u>1985</u>	<u>1990</u>	<u>2000</u>
National Petroleum Council (1972)					
Case I	10.2	13.6	15.5	-	-
II	10.2	12.9	13.9	-	-
III	9.8	11.6	11.8	-	-
IV	9.6	8.9	10.4	-	-
Standard Research Institute (1972)	10.5	11.5	-	14.5	-
Shell Oil Co. (1974; crude oil and NGL)	10.0	10.6	11.4	12.3	-
British Petroleum (1973)	10.3	11.5	11.5	-	-
M. King Hubbert (1974)	10.1	10.1	9.2	-	6.2
Dept. of the Interior (1974, unpublished)	10.4	11.9	14.5	-	13.6
Ford Foundation Energy Policy Project (1974)					
"Historic Growth"					
High Imports	-	11.2	11.2	-	10.5
High Fossil Fuel	-	12.8	14.4	-	19.2
High Nuclear	-	11.2	11.2	-	10.5
"Technical Fix"					
Base Case	-	-	11.9	-	14.9
Low Nuclear	-	-	13.7	-	15.2
High Nuclear	-	-	11.9	-	11.9
M.I.T. (1974; crude oil and NGL)					
\$ 7.00/bbl	-	10.5	-	-	-
9.00/bbl	-	12.6	-	-	-
11.00/bbl	-	14.8	-	-	-
National Academy of Engineering (1974; crude oil and NGL)	-	-	12.5	-	-
Atlantic Richfield Co. (1974)	-	-	15.3	-	-
Hendrick S. Hauthakker (1974; crude oil & NGL)					
\$ 4.00/bbl			12.1		
7.00/bbl			15.1		
10.00/bbl			17.6		
David G. Snow (1974; crude oil and NGL)	10.2	14.6	15.5		

ORIGINAL PAGE IS  
OF POOR QUALITY

TABLE I.1-3. TOTAL CAPITAL INVESTMENT REQUIRED FOR PROJECTED UNITED STATES EXPLORATION AND PRODUCTION OF CRUDE OIL, NATURAL GAS LIQUIDS, HEAVY CRUDES, AND TAR SANDS [PI-74-2, IV-20]  
(Millions of dollars at minimum acceptable prices in the year stated)

A. Business-as-Usual Alternative

Region or source	1974			1977			1980			1985			1988		
	\$4	\$7	\$11	\$4	\$7	\$11	\$4	\$7	\$11	\$4	\$7	\$11	\$4	\$7	\$11
Prudhoe Bay	655	655	655	655	655	655	335	335	335	335	335	335	0	0	0
N. Slope	0	0	0	0	0	378	0	0	744	0	0	0	0	0	0
1	26	48	48	26	78	78	0	143	143	0	303	303	0	500	500
2	31	167	195	31	31	242	74	74	743	92	92	642	94	94	123
2A	10	10	10	46	46	46	102	102	107	183	183	188	33	264	264
3	7	7	61	7	7	65	11	11	73	6	6	105	7	7	125
4	24	24	93	24	24	136	39	39	195	29	29	243	31	31	276
5	105	286	392	105	105	449	168	168	942	126	126	1406	129	129	335
6	79	284	284	79	320	325	286	561	867	580	902	1677	610	617	1854
6A	231	231	231	282	282	282	419	419	419	630	630	630	662	662	662
7	115	211	211	115	181	195	103	103	247	64	64	308	67	67	344
8-10	13	40	43	13	45	49	23	73	100	23	30	153	23	23	180
11	0	0	1	0	0	9	0	0	14	0	0	24	0	0	28
11A	0	0	0	0	0	0	7	7	7	53	53	53	0	207	207
Tar sands	0	0	0	0	2	2	0	87	87	0	85	85	0	101	101
Heavy crude	0	0	0	0	0	163	0	0	262	0	0	238	0	0	187
Total	1296	1963	2224	1383	1776	3074	1567	2122	5285	2121	2838	6390	1656	2702	5186



TABLE I.1-4. MATERIALS AND MANPOWER SUMMARY, BUSINESS-AS-USUAL, \$11 PER BARREL - TOTAL U.S. [PI-74, VI-7]

	1977	1980	1985	1988
Production (1000 B/D)	7971	10314	13022	14285
Rigs - onshore	1675	1885	3200	4400
- offshore	266	429	631	789
Platforms - fixed	100	159	228	279
- mobile	188	376	428	522
Tubular goods (1000 tons)	1111.6	1395.8	1562.3	1725.2
Total steel (1000 tons)	3428.3	4042.1	4003.2	4374.1
Seismic crew months	3299	4069	5453	6379
Rigmen-onshore	37570	42226	73396	102276
-offshore	25700	40500	58300	71300

TABLE I.1-5. CAPITAL EXPENDITURE PROJECTIONS FOR DOMESTIC ENERGY INDUSTRIES, 1975-85 [Slick-75]

(Billions of 1974 Dollars Per Year)

	<u>Petroleum Industry Only</u>	<u>Total Energy Excluding Electric Utilities</u>	<u>Total Energy Including Electric Utilities</u>
FEA Project Independence, November 1974	22 <sup>(1)</sup>	25	50
First Chicago Corporation, May 1975	21	24	49
First National City Bank, September 1974	31	46	84
Sun Oil Company, March 1975	27	N.A.	N.A.
Exxon USA, December 1974	20	24	46

(1) Excludes Marketing &  
Chemical ExpendituresTABLE I. 1-6. PROJECTED CAPITAL EXPENDITURE & PHYSICAL FACILITY REQUIREMENTS U.S. ENERGY INDUSTRIES <sup>(1)</sup>, 1975-85 [Slick-75]

	<u>Cumulative Capital Required 1975-85 Inclusive Billion 1974 \$</u>	<u>New Facilities Required</u>
Conventional Oil	195	300,000 wells, 850 offshore platforms, 38-150 MB/D Equivalent Refineries, 90,000 Miles of New Pipelines
Synthetics	16	10-50 MB/D Equivalent Shale Oil Plants, 11,250 MMCFPD Equivalent Coal Gas Plants
Coal	21	145-5 MM Ton/Year Mines 1,100 - 100 Car Unit Trains
Uranium Mining & Processing	12	35 - 2 MM Ton/Year Equivalent Mines & Enrichment Facilities
Total	<u>\$ 244</u>	

<sup>(1)</sup>Excludes Petroleum Marketing & Chemicals & Electric Utilities

TABLE I.1-7. SCENARIO SUMMARIES\* [PMV-74, 66]

Scenario	PERCENT GAIN IN MPG		FUEL ECONOMY IMPROVEMENTS
	1980:	1985	
Baseline	0	0	No improvements in fuel economy relative to 1974 vehicles. Minimum changes to meet statutory emission standards.
A Modest Improvements	28% 17.9 mpg	27% 17.8 mpg	Optimized conventional engines, radial tires, slight weight and aerodynamic drag reductions (in line with announced industry goals). No improvements after 1978.
B Gradual Improvement Thru 1980's	33% 18.6 mpg	52% 21.3 mpg	Steady technological improvement through the 1980's: Weight reduction through materials substitution and minor redesign during the 1970's; further changes (unitized body) in the 1980's. Some aerodynamic drag reduction and substantial transmission improvements fully accomplished by 1984. Diesel engines phased in for larger cars from 1981 to 1989 plus some stratified charge engines for smaller cars. No performance degradation.
C Maximum Improvement by 1980	43% 20.0 mpg	44% 20.2 mpg	Maximum rate of improvement through 1980 with little further gain during the 1980's. Rapid weight reduction, aerodynamic drag reduction, and transmission improvements. Displacement reduction of optimized conventional engines, but no diesel or stratified charge engines.
D Scenario B Plus Shift to Smaller Cars	63% 22.8 mpg	84% 25.8 mpg	Same as B with 1980 sales mix assumed at 10 percent large cars, 25 percent intermediates, 25 percent compact, and 40 percent subcompact.

\* The base year for comparison is 1974. That year, according to [PMV-74-31], the production-weighted average fuel economy of the three sizes of cars -- small, mid-size, and large -- was 14.0 mpg on the EPA composite driving cycle. The breakdown by class is: small -- 22.3 mpg; mid-size -- 13.1 mpg; large -- 10.7 mpg.

TABLE I.1-8 . ESTIMATED 1980 IMPACTS OF FUEL ECONOMY  
IMPROVEMENTS UNDER SCENARIO C  
(DOLLARS/CAR)

	% Gain in MPG	Increase in Initial Price	PV <sup>(1)</sup> of Fuel Savings	PV of Maintenance Savings	Net Savings
SUBCOMPACT	24.4	242	335	213	306
COMPACT	42.6	249	688	308	747
INTERMEDIATE	42.6	249	937	308	966
STANDARD	61.0	296	1,397	389	1,490
LUXURY	61.0	296	1,465	389	1,558

<sup>1</sup>PV = Present value calculated with a 10% discount rate, gasoline price of 55¢ per gallon, and a ten year period. A 20 percent discount rate would lower the present value of fuel savings by 24 percent.

TABLE I.1-9. NET PRESENT VALUE SAVINGS FROM THE PURCHASE  
OF FUEL EFFICIENT VEHICLES<sup>(1)</sup>  
(DOLLARS/CAR)

	SCENARIO				
CAR SIZE	A	B	B <sup>(2)</sup>	C	C <sup>(3)</sup>
SUBCOMPACT	330	374	513	306	354
COMPACT	612	685	873	747	838
INTERMEDIATE	868	911	1,510	996	1,117
STANDARD	1,103	1,217	1,824	1,490	1,504
LUXURY	1,151	1,276	1,900	1,558	1,543

<sup>1</sup>Computations follow the outline of Table I.1-8 above.

<sup>2</sup>Post 1980 vehicles with diesel engines and/or other improvements.

<sup>3</sup>1982 vehicles under Scenario C.

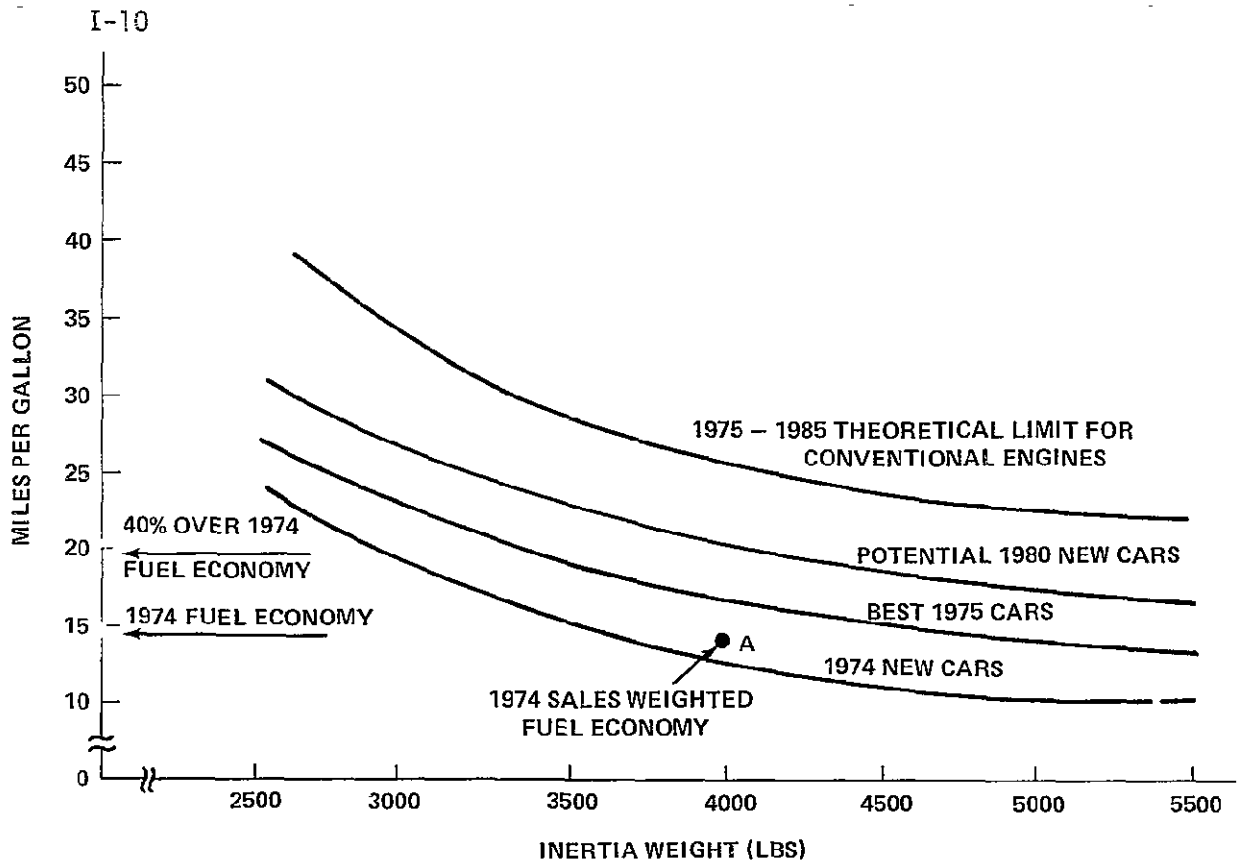


FIGURE I.1-2. 1975-1985 TECHNOLOGICAL POTENTIAL FOR FUEL ECONOMY [PMV-74, 35]

TABLE I.1-10. SAVINGS ON ANNUAL OIL IMPORT COSTS AT \$11/bbl  
(billions of dollars) [PMV-74-71]

YEAR	SCENARIO				
	Baseline	A	B	C	D
1975	0	0.4	0.4	0.6	0.6
1980	0	3.3	4.0	5.0	6.0
1985	0	6.3	8.5	8.9	12.0
1990	0	7.5	12.2	10.9	16.1

The major features of Action 6 to be reviewed are:

A directive to convert all multi-fuel central power plants using gas to oil or coal.

An order to utilize only coal in all plants with appropriate facilities to burn coal.

A provision empowering the FEA administrator to order oil or gas-fired power plants or industrial boilers to retrofit facilities to burn coal should the administrator judge such a conversion in the public interest.

Exceptions would be made wherever alternate fuels are not available, where service interruptions would be required, or where conversion is not deemed in the public good.

In order to demonstrate the effects of the action it has been decided to consider four possible cases:

Extension of FEA authority to order conversion of oil and gas-fired units to coal is denied. Plants on line continue to burn current fuel mix.

FEA orders sufficient conversion to meet natural gas shortfall. All plants with coal facilities are ordered to burn coal. [Power-75,33]

FEA orders all gas burning plants to burn alternate fuels. Any down-rated capacity is assumed to be supplemented with oil-fired combustion turbines. All plants with facilities to burn coal are converted to coal.

FEA orders all gas burning plants to burn alternate fuels. Any down-rated capacity is supplemented with oil-fired combustion turbines. All plants with facilities to burn coal are converted to coal. Fifty percent of all remaining oil-fired plants are converted or replaced by coal-fired units.

The selection of 50% retrofitting is somewhat arbitrary but is justified on the basis that not all plants are judged convertible. Combustion turbines, plants without rail or barge access, or plants without sufficient land for coal storage would be excluded. Moreover, many of the aged plants cannot feasibly convert either on the basis of economic considerations or from consideration of the energy investment.

Direct fuel requirements for the four actions are shown in Table I.2-1. The magnitude of the natural gas shortfall was 1.1 trillion cubic feet per year in 1973. [H.R. 7014 Hearings-75,1107]. Since more recent data has not been available, this value is used for the initial conversion. In the case of conversion to end the shortfall and conversion of the FEA designated convertible plants, it may be noted that oil requirements also drop  $21.2 \times 10^6$  bbl/year. Assuming a price of \$11/bbl, the direct

TABLE I.2-1. DIRECT IMPACTS OF ACTION 6 ON FUEL MIX

	1974 Consumption	Conversions to end natural gas shortfall. Mandatory coal use.	All natural gas plants converted. Mandatory coal use	All natural gas plants converted. Mandatory coal use. Half of discretionary plants converted
Oil, bbl/year	$527.1 \times 10^6$	$505.9 \times 10^6$	$947.7 \times 10^6$	$473.8 \times 10^6$
Gas, mmcf/year	$3.4 \times 10^6$	$2.3 \times 10^6$	None	None
Coal, tons/year	$389.3 \times 10^6$	$427.31 \times 10^6$	$427.31 \times 10^6$	$503.8 \times 10^6$

TABLE I.2-2. COAL AVAILABILITY FOR POWER PLANT USAGE [Murphy-75]  
(millions of tons/year)

	1974	1977 (expected)	1977 (optimistic)
Total Coal Production	601	685	735
Coal Availability for Power Plants	389	431.6	463
Action a. Power Plant Fuel Requirements for existing plus new coal burning units	389	429	429
Action b or Action c Power Plant Fuel Requirements for existing and FEA designated convertible plants		467	467
Action d Power Plant Fuel Requirements for Coal units including all FEA designated plants and 50% of oil burning plants		581	581

savings in annual cash outflow is \$233.2 million. The corresponding increase in coal requirements is  $38 \times 10^6$  tons. It is not altogether clear when such quantities of fuel will be available. Both power plant construction and mine development require significant lead times; thus, future coal requirements and availability may be projected up to at least three years with a relatively high degree of accuracy. The scheduled start-ups of new fossil fuel-fired plants [EW-75,58] and openings of new mines [Murphy-75] show no expected surplus of coal by 1977 (refer to Table I.2-2). However, aggressive mine development could produce an additional  $31.4 \times 10^6$  tons/year by that date. While this is not enough additional fuel to allow conversion of all FEA coal designated plants, it does allow for significant conversion. The differential coal requirements could be made up through imports. While the prospect of coal importation has not been seriously considered, it does offer several notable advantages. Low sulfur, high BTU coal is available in limited quantities from Australia, Poland and South Africa at a price below the equivalent cost of imported oil. The use of coal from these areas would:

Diversify fuel supply and reduce dependence on Arab oil.  
This would lessen the impact of any future embargo.

The expanded coal market (beyond U. S. production) should stimulate coal development in the country. Mine development can only be encouraged by an enlarged market.

The pro-western governments of Australia and South Africa would benefit.

Substitution disrupts the oil cartel and encourages competition in world oil prices.

U. S. balance of payments would be eased by using coal rather than oil.

Using a value of \$11/bbl for oil as compared to \$26/ton for coal, it is found that conversion of the FEA designated plants to coal would reduce annual fuel costs from \$1.77 billion to \$.988 billion. This is an annual improvement in the balance of payments of \$.783 billion, even if all coal is imported. Conversion costs are estimated at \$11.9 billion under present state environmental implementation plans but would drop to \$0.6 billion (1980 dollars) if standards were relaxed to the primary and secondary federal ambient standards. [Allen-75] It is apparent that the economic feasibility of such a conversion is directly related to the environmental standards. Many of the utilities and coal producers advocate a review of environmental standards with a trade-off between the national needs of environmental conditions and energy needs.

Retrofitting of boilers to utilize coal in plants not designed for coal has previously been proposed. The costs of such a retrofit program



has been estimated at \$26 billion (1980 dollars) exclusive of capital required to meet air pollution control requirements or of capital outlays by supporting railroad, etc. [Allen-75] As noted from Table I:2-2, sufficient coal supplies are simply not available to accomplish such a conversion prior to 1978. It is clear that any retrofit program will be hampered by the rate at which additional mines can be developed and should be delayed until coal production surpluses can be attained. Note that the cost of retrofit is of the same order of magnitude as the cost of the coal gasification programs in Appendix D. Both programs provide about 3 quads of additional pipeline gas and both cost on the order of \$30 billion. However, gasification plants would be new facilities with a 40 year lifetime, whereas retrofitting of old natural gas plants would provide significantly shorter service.

An additional area of concern is conversion to coal in transportation. Rail facilities, particularly in the Northeast, have deteriorated over the past several years and will require ungrading. Today there is both a shortage of hopper cars and coal barges such that significant problems may occur in transport. The problem will be accentuated by development of the low sulfur coal areas of the Northern Great Plains. While rail lines are generally in good repair in this region, the distance to major population areas is enormous. Barge transport is generally much cheaper than rail, but no waterways of sufficient depth are found in the area. Generally, it is recognized that rail transport will be required at least to the Mississippi River. From there, coal may move east either up the Ohio River or down through the Gulf. Transportation by rail provides a significant side benefit of providing substantial revenues to rail systems. In fact, coal transport constitutes the railroads' single most important commodity class. Thus, conversion to coal serves to stabilize rail revenues.

In conclusion, it is noted that conversion of the FEA designated plants can be accomplished by 1977, given an aggressive coal development program. Moreover, conversion of 1.1 quads of gas-fired plants would serve to alleviate the current shortfall of natural gas for residential, commercial and other industrial users.

## APPENDIX J. ELECTRIFICATION

### J.1 INTRODUCTION

This appendix will contain most of the tables and figures supporting the discussion in Chapter 10. Impacts will also be discussed here.

### J.2 ENERGY INDUSTRY ACTIONS

#### J.2.1 INCREASE POWER GENERATION FROM COAL

Project Independence [PI-74] has adequately discussed the requirements and impacts of an expansion of coal production. Chapter 9 of ECASTAR discusses some of the indirect coal requirements which are entailed by an expansion of coal production and substitution of coal for oil and gas. These indirect requirements are large and divert coal away from net sales as energy to sales for production requirements, e.g. steel. Thus, indirect requirements must be estimated carefully in planning the rate of expansion of the coal supply in the critical near-term.

#### J.2.2 INCREASE THE USE OF NUCLEAR POWER

The nuclear picture is almost entirely in the future. Therefore most of what can be said depends on scenarios of financial health, safety and reliability, and public acceptance. The only major actors in the nuclear picture are Light Water Reactors (and a few HTGR) and the Liquid Metal Fast Breeders. The breeder is definitely not a commercial item in the near or mid-term. No major new design concepts are being pursued in non-breeder reactors.

Two scenarios are presented in Figure J.2.2-1, the Westinghouse base case [WEST-75], and the projected growth rate according to the number of reactors planned by the nuclear industry. The latter includes reactors in operation, under construction, and those ordered but in the planning stage [NEI-75]. It is based on Figure J.2.2-2, which shows the number of reactors and the total gigawatt (rounded-off numbers) to be added per year. Note that in 1985 about 190 GWe are projected while the Westinghouse scenario predicts 206 GWe.

The Westinghouse scenario foresees a reversal in the downward trend of reactor additions, contrary to the indications of the number of reactors planned by 1985. In assessing requirements, the nuclear forecast according to actual reactor orders will be used (Figure J.2.2-2).

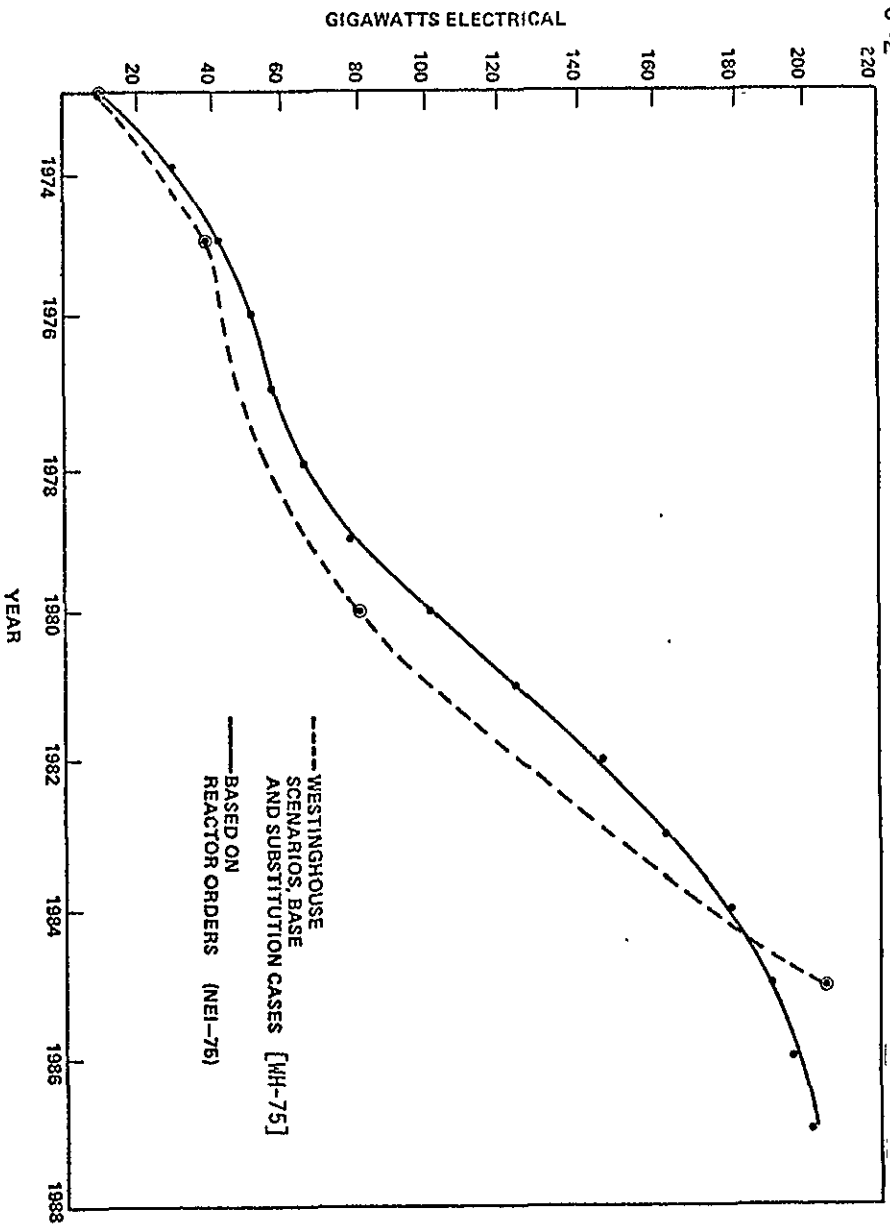


FIGURE J.2.2-1 FORECAST OF NUCLEAR POWER GROWTH

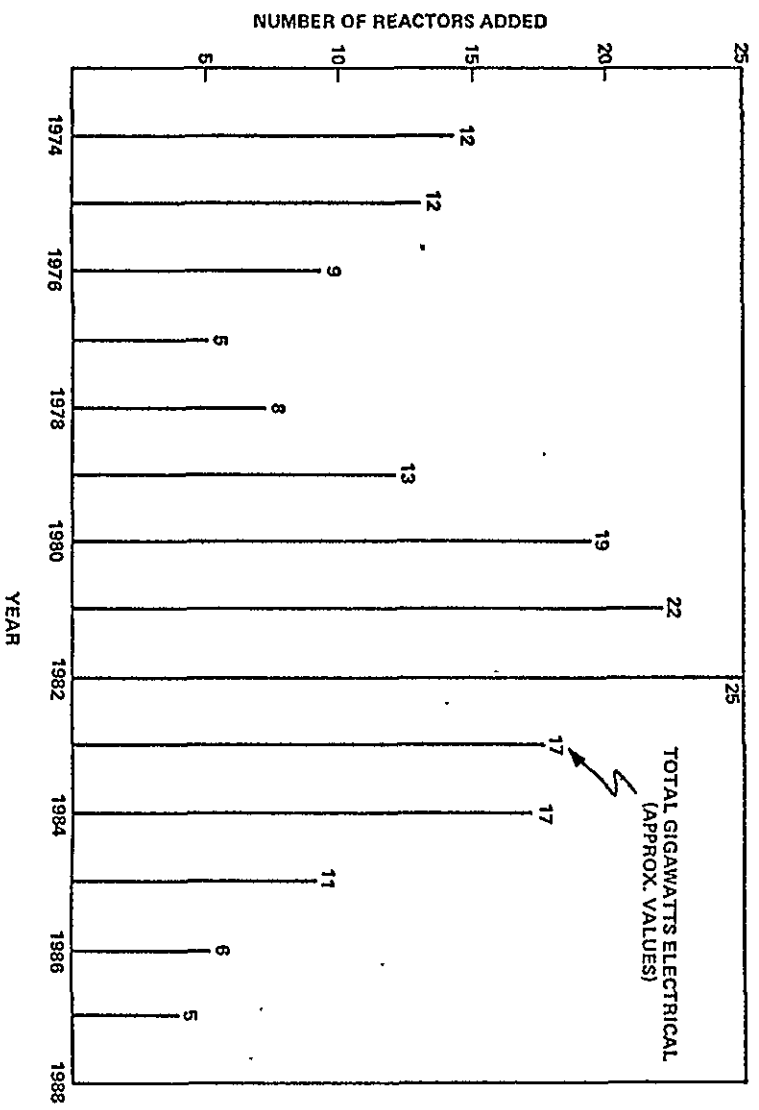


FIGURE J.2.2-2 NUCLEAR REACTORS PLANNED PER YEAR [NEI-75]

A total of 158 reactors (151 LWRs and 7 HTGRs) are projected to be installed between 1975 and 1985. Although some of the reactors will be part of a two or three plant units, the calculations will be based on single power units of 1 GWe (an average value; beyond 1979 most of the reactors are between the 1.1 and 1.3 GWe range). Including the present capacity, a total of about 190 reactors will be operating by 1985.

Some of the most important requirements for the mining and milling operations are given in Table J.2.2-1. The requirements are based on the open pit mines and mills equivalent to the Anaconda Co. operations in Grants, New Mexico.

Unit requirements for other nuclear processing facilities are presented in Table J.2.2-2.

$U_3O_8$  requirements are given in Table J.2.2-3. The results are based on Table J.2.2-4.

At a rate of 360,400 lbs  $U_3O_8$  per year per GWe, the  $U_3O_8$  requirements by 1985 will be of the order of 30 thousand tons/year. The cumulative requirements by 1985 are about 936 replacement reactor core loadings, corresponding to about 153 thousand tons of  $U_3O_8$ . Cumulative initial core loadings to 1985 amount to about 62 thousand tons. These represent a total cumulative  $U_3O_8$  requirement of about 215 thousand tons. This amount is within the United States proven reserves, Figure J.2.2-3. There have been some reductions in the quantities shown in this figure [HOGERTON-75]; however, they still satisfy  $U_3O_8$  needs to 1985.

Thorium needs are presented in Table J.2.2-5. Considering the large availability of thorium and the number of HTGRs (6 GWe total) expected to be in operation by 1985, the HTGRs fuel requirements can be met.

The required conversion capacity ( $U_3O_8$   $UF_6$ ) at 138.6 metric tons of uranium per year per GWe will be about 26,000 metric tons/year. Three conversion plants are currently operating in the United States. These are Kerr-McGee's 4500 ton/year plant at Sequoyah, Oklahoma; Allied Chemical's 12500 ton/year plant near Metropolis, Illinois; and ERDA's (NRC) 8000 ton/year plant at Fernhold, Ohio. Kerr-McGee plans to increase its capacity to 9000 ton/year by 1977. The 29,500 metric ton/year total capacity identified above is sufficient to meet annual conversion demands in the year 1985.

Table J.2.2-6 presents the separative work requirement for uranium fuel enrichment calculated from Table J.2.2-7. Replacement loadings per year in 1985 are projected to be about 23 million SWUs. From Figure J.2.2-4, it can be seen that with the improved plants, at any of the tails assays indicated, the requirements can be met.

TABLE J.2.2-1. MINING AND MILLING REQUIREMENT (1985)\*

Number of Mines (1500 tons $U_3O_8$ /mine)**	20
$U_3O_8$ (tons/year) (163 tons/GWe/year)	30,143
Rubber and Steel for Mining	
Equipment and Trucks:	
Rubber (tons)	2750
Steel (tons)	3000
Engineering and Supervisory	
Manpower (persons/operating day):	
Mines	343
Mills	285
Other Manpower (per operating day)	
Mines	6500
Mills	5415
Total Manpower (per operating day)	
Mines	6843
Mills	5700
Concrete (yd <sup>3</sup> )	7500
Total Steel (tons)	32,500
Water Used in Milling (gallong/day)	$3.75 \times 10^7$
Capital Outlay (dollars)	
Steel	456,000
Concrete	80,520
Cumulative Capital Outlay in 5-year Periods for Mining and Milling Facilities (Million dollars)	220
Energy Consumed (mining, milling and transportation of ore from mine to mill) (kWh)	$21 \times 10^7$
Capital (investment in mill, equipment and land) (Million dollars)	450

\* Based on [MEGASTAR-75] Appendix B-3

\*\* Open pit mines and mills equivalent to the Anaconda Co. operations in Grants, New Mexico

ORIGINAL PAGE IS  
OF POOR QUALITY

TABLE J.2.2-2. UNITS REQUIREMENTS FOR NUCLEAR FACILITIES [MEGASTAR-74]

Requirements	Plant (Capacity)			
	U <sub>3</sub> O <sub>8</sub> Conversion (9000 tonnes/yr)	Gas Diffusion (8.75x10 <sup>6</sup> SWU/yr)	Fuel Fabrication (1200 tonnes UO <sub>2</sub> /yr)	Fuel Reprocessing (1500 tonnes/yr)
Construction Designers (10 <sup>6</sup> man-hrs)	1	?*	1	Comparable
Craftsmen (10 <sup>6</sup> man-hrs)	2	24	2	to Power Plant
Leadtime (years)	4		6	9
Steel (tons)	-*	7x10 <sup>4</sup>	-	6x10 <sup>4</sup>
Concrete (yd <sup>3</sup> )	-	3x10 <sup>5</sup>	-	6x10 <sup>3</sup>
Land (acres)	80	400	100	1000
Operating Personnel	50	900	1200	350
Power	-		-	-
H <sub>2</sub> O (gpd)	-	2x10 <sup>7</sup>	-	-
Capital (\$million)	37		50	270

\* (- means probably negligible, ? means may be important but not yet available)

\*\* Based on cost  
enrichment plan in Alabama

TABLE J.2.2-3.  $UO_3$  REQUIREMENTS TO 1985<sup>a</sup>

Feed Required ( $10^3$ Kgs $U_3O_8$ )	BWR <sup>b</sup>	PWR <sup>b</sup>
Initial Cores <sup>c</sup>	22,455	38,747
Replacement Loadings/year <sup>d</sup>	10,134	19,940

a) Based on Table J.2.2-4. HTGR's not included.

b) It was assumed 2 PWRs to 1 BWR

c) Based on 151 LWRs of 1 GWe

d) Based on 184 LWRs of 1 GWe

TABLE J.2.2-4. CALCULATION OF  $U_3O_8$  YELLOWCAKE AND  $U^{238}$  REQUIRED ANNUALLY FOR A MODEL LIGHT WATER REACTOR ECAC-137P-74]

Assume: Plant size = 1000 MWe  
 Enrichment tails assay = 0.20 percent  $U^{235}$   
 Load factor = .75

Feed Required (lbs $U_3O_8$ )	BWR	PWR
Initial core	988,000	844,000
Replacement loadings	288,000	308,000
10 year average	358,000	361,600
30 year average	311,333	325,867

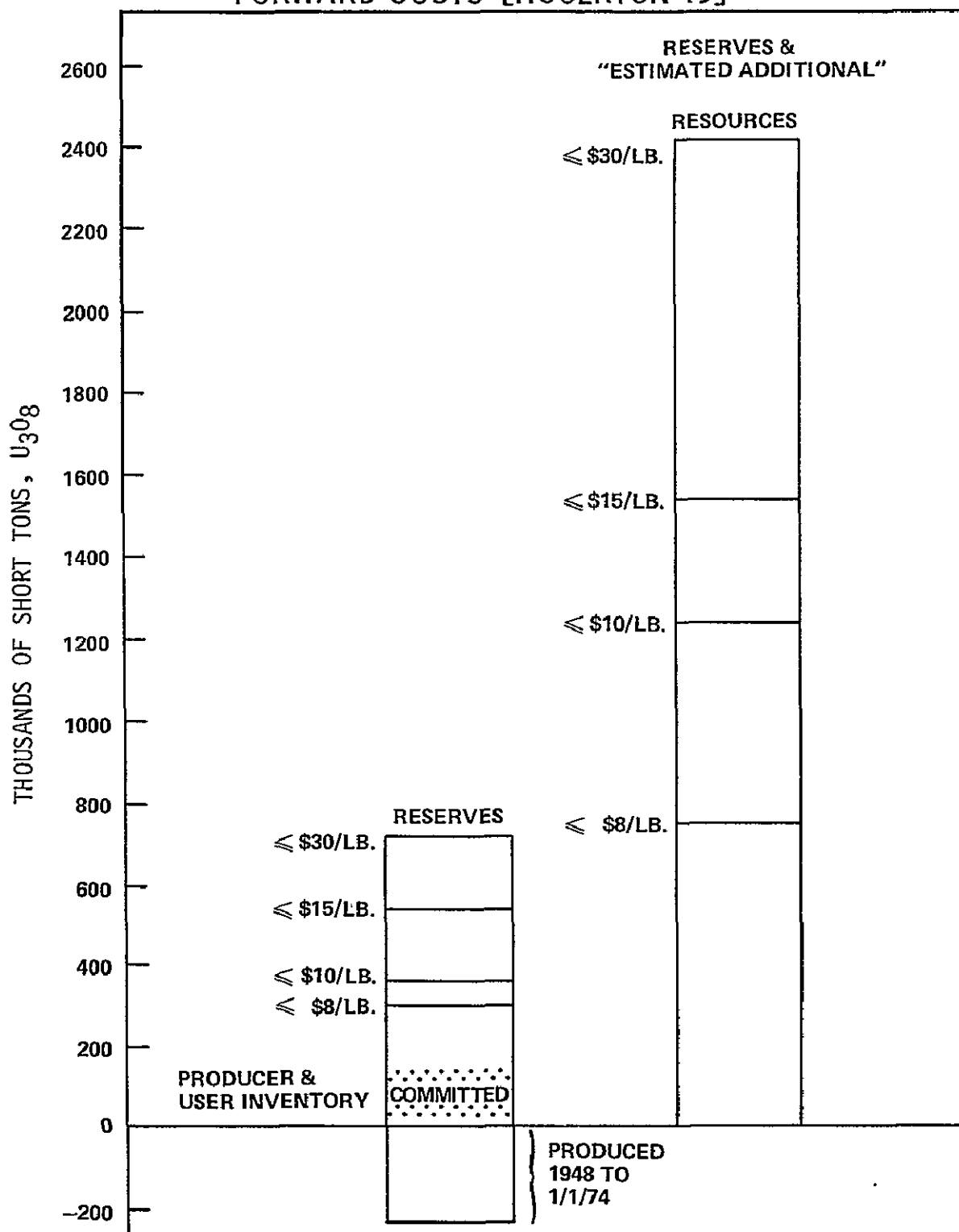
[Assume: 2 PWR's to 1 BWR]

	LWR
10 year average	360,400
30 year average	321,022

Feed Required (kgs $U_3O_8$ )	LWR
10 year average	163,447
30 year average	145,588

Feed Required (kgs U)	LWR
10 year average	138,600
30 year average	123,456

# U.S. URANIUM RESOURCE STATUS AT DIFFERENT FORWARD COSTS [HOGERTON-75]\*



\*AS OF JANUARY 1, 1974

FIGURE J.2.2-3



J-8

TABLE J.2.2-5. THORIUM REQUIREMENTS PER YEAR FOR A 1 GWe PLANT (Metric Tons)

Mining Requirements	16
Fuel Fabrication Loads	12
Fuel Reprocessing	3

TABLE J.2.2-6. SEPARATIVE WORK REQUIREMENTS<sup>a</sup>

Separative Work (10 <sup>3</sup> Kg SWU)	BWR <sup>b</sup>	PWR <sup>b</sup>
Initial Cores <sup>c</sup>	11,950	22,422
Replacement loadings/year <sup>d</sup> (10 year average)	7,341	15,555

- a) Based on Table J.2.2-7. HTGR's not included.  
b) It was assumed 2 PWRs to 1 BWR  
c) Based on 151 LWRs of 1 GWe  
d) Based on 184 LWRs of 1 GWe

TABLE J.2.2-7. CALCULATION OF SEPARATIVE WORK REQUIRED ANNUALLY FOR A MODEL LIGHT WATER REACTOR [CAC-137P-74]

Assume: Plant size = 1000 MWe  
Enrichment tails assay = 0.20 percent U<sup>235</sup>  
Load factor = .75

<u>SWU's Required (kg SWU's)</u>	<u>BWR</u>	<u>PWR</u>
Initial core	239,000	222,000
Replacement loadings	105,000	117,000
10 year average	118,400	127,500
30 year average	109,467	120,500

[Assume: 2 PWR's to 1 BWR]

	<u>LWR</u>
10 year average	124,467
30 year average	116,822

J-9

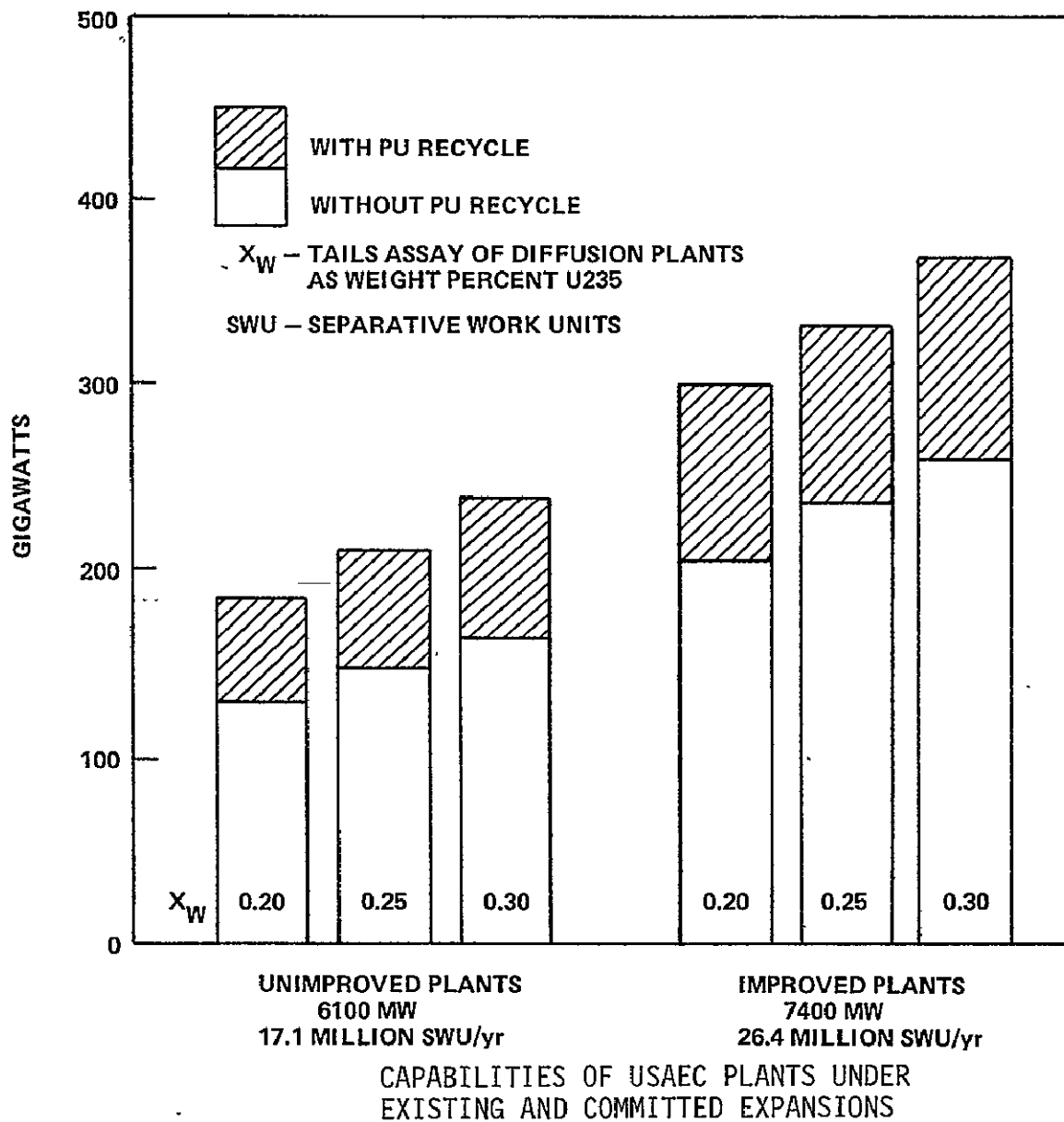


FIGURE J.2.2-4

CAPACITY OF GASEOUS PLANTS TO SUPPLY  
 LIGHT WATER REACTORS [Creagan-74]

Fuel preparation and fabrication requirements at 30 metric tons of uranium/year/GWe will be about 5700 metric tons/year during 1985. The U. S. capacity projected for 1980 is 8,200 metric tons/year, sufficient to meet requirements. At the present, the annual capacity is estimated at 4500 tons.

The fuel cycle costs per year by 1985 are tabulated in Table J.2.2-8. These results are derived from Table J.2.2-9, which assumes fuel cycle needs corresponding to 10 years after operation. In general, the plant load factor increases with plant operating time, hence, a larger load of fuel is consumed per year as the plant gets older. Note that safeguarding, insurance, and power plant decommissioning are not included in the fuel cycle cost.

Construction craft manpower requirements for the period between 1975 and 1982 are presented in Figure J.2.2-5. The data in this figure was obtained from Figures J.2.2-2 and J.2.2-6. The manpower distribution for a one-unit power plant was approximated by a triangular distribution extending over a six-year period and with a maximum of 1.3 men/KWe. This approximation underestimates manpower. However, since not all power plants are a one-unit plant, this tends to compensate for the approximation. Note that for the double-unit the peak is 1.05 men/KWe.

Major construction material requirements for a typical 1.1 GWe nuclear power plant are given in Table J.2.2-10. The various ranges of quantities are shown to reflect the various differences among plants and design aspects [BUDWANI-75]. Table J.2.2-11 lists other materials and equipment for a 1 GWe PWR power plant.

Based on a nuclear plant completion time of ten years, Table J.2.2-12 gives the combined nuclear utility and direct support staffing schedules. Table J.2.2-13 presents a typical nuclear utility operations staff. HTGR staffing requirements are not presented since they constitute a small fraction of the total manpower needs by 1985.

Shipment requirements in the nuclear fuel cycle and quantities of nuclear waste generated are presented in Table J.2.2-14. Ten types of radioactive wastes are defined on the basis of their characteristics and of their packaging, shipping and disposal requirements.

### Impacts

Impacts are assessed on the environmental, economical, social and political aspects of society.

The discussion of environmental impacts will be restricted to public health and safety and to ecological changes that might result from radioactive releases and waste heat discharges during operations in the nuclear fuel cycle.

TABLE J.2.2-8. FUEL CYCLE COSTS PER YEAR IN 1985<sup>a</sup> (Million Dollars/Year)

<u>Cost Component</u> <sup>b</sup>	<u>Cost/Year</u>
a) Mining and Milling	1327
b) Conversion to UF <sub>6</sub>	128
c) Enrichment	2222
d) Fuel Prep and Fabrication	612
e) Spent Fuel Shipment	40
f) Reprocessing	273
g) Reconversion	10
h) Waste Management	80
i) Shipping	26
	<hr/>
Subtotal	4718
j) Fuel inventory carry charge	---
k) Safeguarding	---
l) Insurance	---
m) Plant decommissioning	---
	<hr/>
Total	4718

a) HTGR are not included

b) Based on Table J.2.2-9

TABLE J.2.2-9. 1980 FUEL CYCLE COSTS FOR AN AVERAGE 1000 MWe NUCLEAR POWER PLANT (1980 dollars) (10 YEAR OPERATION) [CAC-137P-74]

<u>Cost Component</u>	<u>Cost/Unit</u>	<u>Quantity/Yr.</u>	<u>Cost/Yr.</u>	<u>mills/kwhe</u>
a) Mining and Milling	\$20/lb $U_3O_8$	360,400 lbs $U_3O_8$	\$7,208,000	1.10
b) Conversion to $UF_6$	\$5/kg U	138,600 kg U	\$693,000	0.10
c) Enrichment	\$97 kg SWU	124,467 kg SWU	\$12,073,299	1.84
d) Fuel Prep and Fabrication	\$29,679 kg U	29,679 kg U	\$3,324,048	0.50
e) Spent Fuel Shipping	\$8/kg U	26,525 kg U	\$212,200	0.03
f) Reprocessing	\$56/kg U	26,525 kg U	\$1,485,400	0.23
g) Reconversion	\$2/kg U	26,181 kg U	\$52,362	0.01
h) Waste Management	\$16/kg U (reactor fuel)	27,345 kg U (reactor fuel)	\$437,520	0.07
i) Shipping				
b) to c)	\$.42/kg U	137,907 kg U	\$57,921	
c) to d)	\$.90/kg U	29,679 kg U	\$27,711	
d) to e)	\$.72/kg U	28,937 kg U	\$20,835	
f) to g)	\$1.45/kg U	26,260 kg U	\$38,077	
Shipping total			\$143,544	0.02
Subtotal			\$25,629,373	3.90
j) Fuel Inventory Carrying Charge (at 12%)			\$8,672,400	1.32
k) Safeguarding			NA	-
l) Insurance			NA	-
Total (without k and l)			\$34,301,773	5.22

## Assumptions:

Load factor = .75

Burnup = 29,883 MW(t)D/MTU

Efficiency = 33.5 percent

Inflation rate = 7 percent annually

Plant operation = 10 years

ORIGINAL PAGE IS  
OF POOR QUALITY

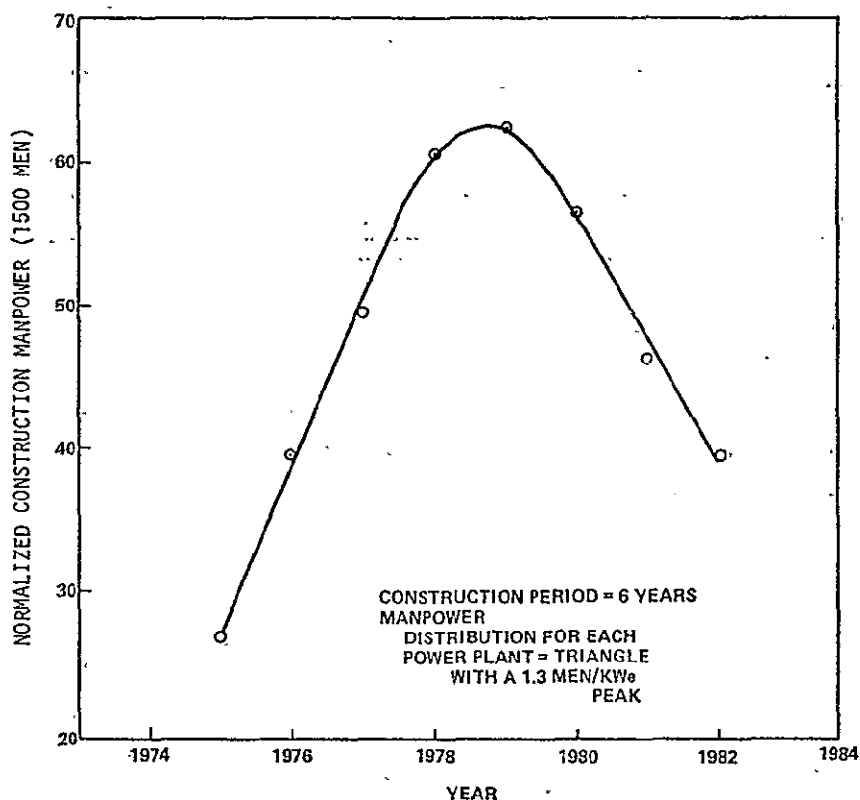


FIGURE J.2.2-5 TOTAL CONSTRUCTION MANPOWER REQUIREMENTS FOR REACTORS PLANNED

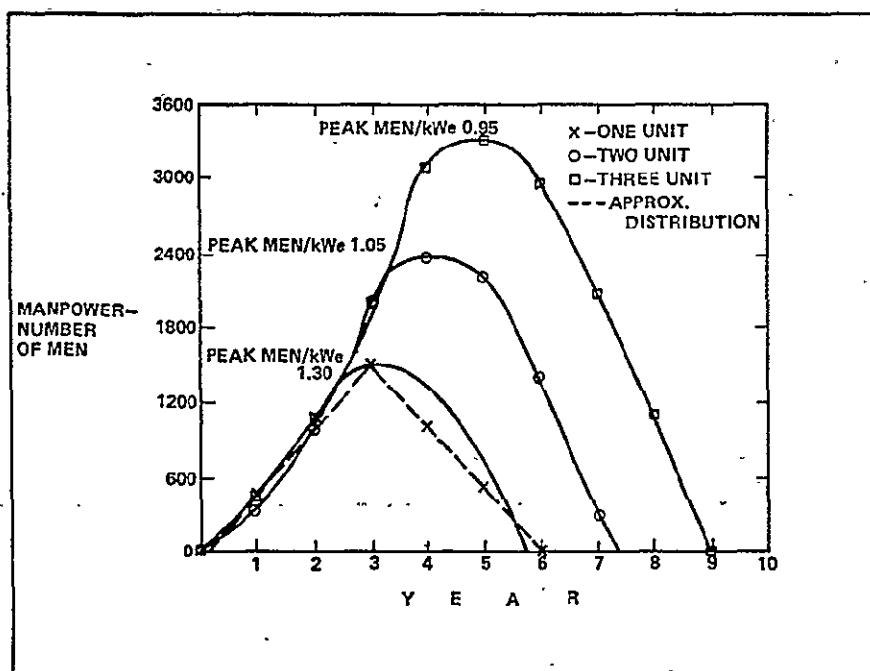


FIGURE J.2.2-6

TOTAL CRAFT MANPOWER REQUIREMENTS YEAR BY YEAR FOR TYPICAL ONE-UNIT, TWO-UNIT, AND THREE-UNIT NUCLEAR POWER PLANTS OF 1150-MWe CAPACITY PER UNIT. PEAK NUMBER OF MEN PER MWe IS SHOWN FOR EACH CURVE. BUDWANI-75

TABLE J.2.2-10. MAJOR CONSTRUCTION MATERIAL REQUIREMENTS FOR A TYPICAL 1.1 GWe NUCLEAR POWER PLANT [BUDWANI-75]

MATERIAL	QUANTITY		
Concrete	125,000	to	175,000 cu yd
Rebar	13,000	to	18,000 tons
Structural steel	5,000	to	8,000 tons
Containment liner (PWR)	900	to	1,200 tons
Fuel pool liner	140	to	160 tons
Embedments (iron)	1,000	to	1,200 tons
Formwork	1,250,000	to	1,750,000 sq ft
Cable trays	60,000	to	90,000 lin ft
Conduit (metallic)	325,000	to	550,000 lin ft
Condenser tubing	3,000,000	to	3,500,000 lin ft
Railroad tracks	40,000	to	60,000 lin ft
Piping 2½ in. and over	2,850	to	3,350 tons
Grating and flooring	225	to	350 tons
Cable (power and control)	3,250,000	to	4,500,000 lin ft

TABLE J 2.2-11. MATERIALS AND EQUIPMENT FOR 1-1000 MWe PWR GENERATING PLANT  
[DEUTCH-74]

Aluminum:	20 short tons
Cement (total):	50,000 short tons
Concrete (total):	150,000 cubic yards
Copper:	800 short tons
Carbon Steel:	36,000 short tons (includes structural steel, reinforcing steel, steel forgings and castings, plate steel, piping and conduit)
Heavy Steel Plate:	2300 short tons (includes 600 tons for reactor pressure vessel)
Steel Forgings:	350 short tons (for Nuclear Steam Supply System); 200 short tons forging for generator rotor.
Carbon Steel Piping (over 2 inches):	2650 short tons
Stainless Steel:	2300 short tons (includes 375 short tons of stainless steel piping (over 2 inches in size)
Steel Railroad Track:	50,000 feet of rail
Pumps:	44 pumps driven by motors in 0-99 HP range 34 pumps driven by motors in 100-999 HP range 9 pumps driven by motors in 1000-9999 HP range 2 pumps driven by mechanical drive turbines of 12,300 HP each
<p><b>Note:</b> The pumps listed above are identified in the cost estimate listing and the electrical one-line diagram of AEC publication WASH-1230 (Vol. 1). Counting miscellaneous additional pumps, there are on the order of 100 pumps in the model 1000 MWe PWR plant.</p>	
Compressors:	5 (for station service air, instrument air and waste gas; does not include air conditioning compressors)



TABLE J.2.2-11. (Cont.)

**Transformers:**

- 2 main transformers, 570,000 KVA each
- 2 auxiliary power transformers, 43,000 KVA each
- 4 station service transformers, 2,700 KVA each
- 4 transformers in the 0-100 KVA range for 120 volt AC supply, generator neutral, and control circuits

**Note:** In addition to the principal transformers listed above there are miscellaneous small control transformers in this plant switchgear and motor control center as well as instrument transformers for plant relaying, metering and control.

**Turbines:**

- 1 - steam turbine-generator rated approximately 1,100,000 KW
- 1 - gas turbine-generator rated 21,000 KW (stand-by plant startup)
- 2 - turbines rated 12,300 HP each to drive the reactor feedwater pumps
- 1 - turbine (rating not specified) to drive an auxiliary feedwater pump

**Diesels:** 3 diesel generators rated 2000 KW each

**Boilers:** 2 - 50,000 pound per hour oil-fired auxiliary heating boilers

**Valves:** About 350 to 400 main valves are required for the nuclear steam supply and turbine-operator fluid cycle systems. An unidentified number of smaller valves are required for station plumbing and drains and miscellaneous station services.

ORIGINAL PAGE IS  
OF POOR QUALITY

TABLE J .2.2-12. COMBINED NUCLEAR UTILITY AND DIRECT SUPPORT STAFFING SCHEDULES  
(Single Unit, 1100 Mw Nuclear Power Plant)

Year	Utility		Direct Support Organizations				
	Operations Staff	Engineering and Technical Support Staff	Architect Engineer	Nuclear Steam Supply System Vendor	Technical Consultants	Construction Management Organization	Total
	(Engineers/Non-Engineers)	(Engineers/Non-Engineers)	(Engineers/Non-Engineers)	(Engineers/Non-Engineers)	(Engineers/Non-Engineers)	(Engineers/Non-Engineers)	(Engineers/Non-Engineers)
1	0/0	10/0	10/5	5/0	10/0	0/0	35/5
2	0/0	10/0	10/10	10/0	10/0	0/0	40/10
3	0/0	15/5	25/25	15/5	15/0	0/0	70/35
4	0/0	20/5	50/50	15/5	15/0	10/0	110/60
5	0/0	25/10	70/70	15/5	20/0	10/30	140/115
6	5/0	25/10	75/70	15/5	20/0	20/60	160/145
7	15/40	25/10	55/55	15/5	20/0	20/60	150/170
8	15/60	25/10	50/50	15/5	20/0	20/60	145/185
9	15/60	25/10	25/25	10/0	10/0	10/30	95/125
10	15/60	25/10	15/5	5/0	5/0	10/0	75/75
Total Man-Years Prior to Commercial Operation	65/220	205/70	385/365	120/30	145/0	100/240	1,020/925
Man-Years Per Year After Commercial Operation	15/60	15/10	Not Estimated	Not Estimated	Not Estimated	Not Estimated	30/70

TABLE J.2.2-13. TYPICAL NUCLEAR UTILITY OPERATIONS STAFF (Single Unit 1.1 GWe Nuclear Power Plant) [DEUTSCH-74]

Plant Superintendent	1
Assistant Plant Superintendent	1
Operations Supervisor	1
Training Coordinator	1
Shift Supervisors (SRO Licenses)	6
Control Operators (RO Licenses)	12
Auxiliary Operators	12
Technical Supervisor	1
Technical Staff	8
Technicians	12
Maintenance Supervisor	1
Electrical and Mechanical Maintenance Personnel	<u>19</u>
Total	75

TABLE J.2.2-14. SHIPMENT REQUIREMENTS IN THE NUCLEAR FUEL CYCLE (1985)<sup>a</sup>

<u>FRESH FUEL SHIPMENTS</u>	<u>LWR</u>	<u>HTGR</u>
Metric Tons/Year/Reactor <sup>b</sup>	40	12
Load/Vehicle/Metric Ton	5.5	1
Time in Transit, days	1.4	1.4
Shipments/Year <sup>c</sup>	1338	72
Vehicles in Transit (average)	5.13	0.28
<u>SPENT FUEL SHIPMENTS</u>		
Metric Tons/Year/Reactor	23 <sup>d</sup>	3.2
Load/Vehicle (Metric Tons)		
Truck	0.44	--
Rail	3.1	0.6
Shipments/Year <sup>e</sup>		
Truck	3206	--
Rail	910	32
Time in Transit, days	2.5	2.5
Vehicles in Transit (average)		
Truck	22	
Rail	6.23	0.22
Radioactivity/Shipment (Megacuries)	16	3

TABLE J.2.2-14 (Cont.)

<u>PROJECTED SHIPMENTS OF PLUTONIUM</u>	
Metric Tons of Fissile Pu/year	30
Load/Vehicle (Metric Tons)	0.5
Shipments/year	60
Time in Transit, days	2.5
Vehicles in Transit (average)	0.4
<u>SOLIDIFIED HIGH-LEVEL WASTE SHIPMENT</u>	
Rate of Generation (ft <sup>3</sup> /year/GWe)	47
Total Waste (ft <sup>3</sup> /year)	8930
Rate of Shipment (ft <sup>3</sup> /year) <sup>a</sup>	1974
Shipments/year <sup>b</sup>	26
Vehicles in Transit	1
Radioactivity/Shipment (Megacuries)	11
<u>SHIPMENT OF CLADDING WASTE</u>	
Volume/Metric Ton of Spent Fuel/GWe (ft <sup>3</sup> )	2.3
Total Volume Generated (ft <sup>3</sup> /year) <sup>c</sup>	9705
Volume/Shipment (ft <sup>3</sup> ) <sup>d</sup>	95
Shipments/year	102
Vehicles in Transit	1

- a) Based on [BLOMEKE-75]  
 b) Assuming 270,930 lbs of U<sub>3</sub>O<sub>8</sub>/year/GWe  
 c) 184 GWe for LWRs and 6 GWe for HTGRS  
 d) Assuming 22,934 KgU/Year/GWe  
 e) Ratio of rail to truck of 2:1

- a) Waste generated in 1975 is transported as solidified waste in 1985 (42 GWe for 1975)  
 b) 12 waste canisters of 6.3 ft<sup>3</sup> per shipment  
 c) Based on 22,934 KgU/year/GWe

ORIGINAL PAGE IS  
OF POOR QUALITY

TABLE J.2.2-14 (Cont.)

SHIPMENT OF NOBLE GASES FISSION PRODUCTS<sup>a</sup>

Radioactivity Generation (Megacuries/year/GWe)	0.205
Total Radioactivity (Megacuries/year)	39
Cylinders Shipped/year <sup>b</sup>	247
Number of Shipments/year	41
Vehicles in Transit	1
Radioactivity/Shipment (Megacuries)	1

SHIPMENT OF FISSION-PRODUCT IODINE

Iodine Production Rate (Kg/year/GWe)	5.5
Total Iodine Generated (Kg/year)	1045
Radioactivity Generated (Curies/year/GWe)	0.75
Total Radioactivity (Curies/year)	143
Shipments/year	4
Curies/Shipment	36

SHIPMENT OF TRITIUM

## Tritiated Water from Reactors

Tritiated Water Generation (gallons/year/GWe)	20,000
Total Tritiated Water (gallons/year)	3,680,000
Shipments/year <sup>c</sup>	920
Radioactivity Generation (Megacuries/year/GWe)	0.00035
Total Radioactivity (Megacuries/year)	0.0644

TABLE J.2.2-14 (Cont.)

## Tritium from Fuel Reprocessing

Production (ft <sup>3</sup> /year/GWe)	10
Total tritium (ft <sup>3</sup> /year)	1840
Radioactivity (Megacuries/year)	2.85
Shipments/year	190

SHIPMENT OF PLUTONIUM ALPHA SOLID WASTES

Production (ft <sup>3</sup> /year/GWe)	1.2x10 <sup>3</sup>
Total Plutonium Alpha Wastes (ft <sup>3</sup> /year)	221x10 <sup>3</sup>
Shipments/year <sup>a</sup>	221
Vehicles in Transit	5
Radioactivity (Megacuries/year)	2

SHIPMENT OF ALPHA-BETA-GAMMA WASTES

Production (ft <sup>3</sup> /year/GWe)	5.23x10 <sup>2</sup>
Total Waste (ft <sup>3</sup> /year)	10 <sup>5</sup>
Radioactivity (Megacuries/year)	1.6
Shipments/year <sup>b</sup>	1340
Vehicles in Transit	23

SHIPMENT OF BETA-GAMMA WASTES

Production (ft <sup>3</sup> /year/GWe)	4x10 <sup>3</sup>
Total Waste (ft <sup>3</sup> /year)	760x10 <sup>3</sup>
Radioactivity (Megacuries/year)	0.7
Shipments/year <sup>c</sup>	1600
Vehicles in Transit	17

- a) Krypton and Xenon  
b) 50 liter cylinders; 1.3 cylinder/year/GWe; 6 cylinders/shipment  
c) 4000 gallon tank trucks/shipment

- a) 1000 ft<sup>3</sup>/carload by rail  
b) 75 ft<sup>3</sup>/shipment, motor freight  
c) 475 ft<sup>3</sup>, 64 drums (55 gallon drums)/load.

Radioactive releases of appreciable impact might result from nuclear thefts, sabotage, reactor accidents, and spent fuel transportation accidents. Figure J.2.2-7 pictures an impact flow diagram due to these three types of nuclear accidents. The final impact is on public health in terms of somatic (vomiting, loss of hair, etc.) and genetic (long term) effects. Only impacts from reactor accidents are considered in detail.

The effects of waste heat rejection from a power plant are presented in the impact flow diagram in Figure J.2.2-8..

### Impacts from Potential Reactor Accidents

In order to assess the risk to the public from potential accidents in the operation of LWRs commercial power plants, the Atomic Energy Commission (now NRC) performed a study, under the direction of Professor Norman C. Rasmussen, which lasted two years and involved 50 man years of effort and three million dollars. This study which is commonly referred as the "Rasmussen Report," Draft WASH-1400 (AEC-74-4) made a realistic estimate of these risks and compared them with non-nuclear risks to which our present society is already exposed. In this study, risk is associated with the likelihood and consequences of an event.

Using fault-free methodology, the study devoted a large amount of its effort to insure that all potential accidents important in determining the public risk were covered. This systematic approach makes it very unlikely that an accident which would contribute to overall risk was overlooked. Thousands of potential accident paths were defined and examined to determine their likelihood of occurrence and the amount of radioactivity they might release.

Based on the fact that potentially large amounts of radioactivity can only be released by melting of the fuel in the reactor core, the safety study considered two broad types of situations; the loss of coolant accident (LOCA) and nuclear plant transients.

The results of the study are summarized in Figures J.2.2-9 through J.2.2-11. These are based on the operation of 100 nuclear power plants of 1000 MW electrical capacity.

Figures J.2.2-9 and J.2.2-10 compare, in terms of the number of fatalities, the nuclear reactor accident risks with the potential risks from other manmade and natural phenomena, respectively. Figure J.2.2-11 shows the likelihood and dollar value (1973 dollars) of property damage (not including the power plant) associated with nuclear and non-nuclear accidents.

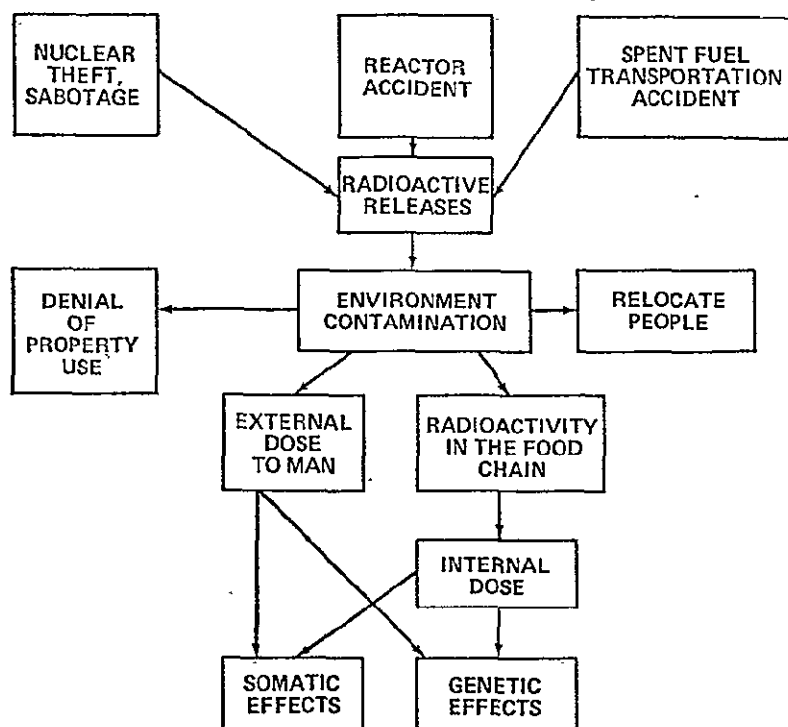


FIGURE J.2.2-7 IMPACTS FROM NUCLEAR ACCIDENTS

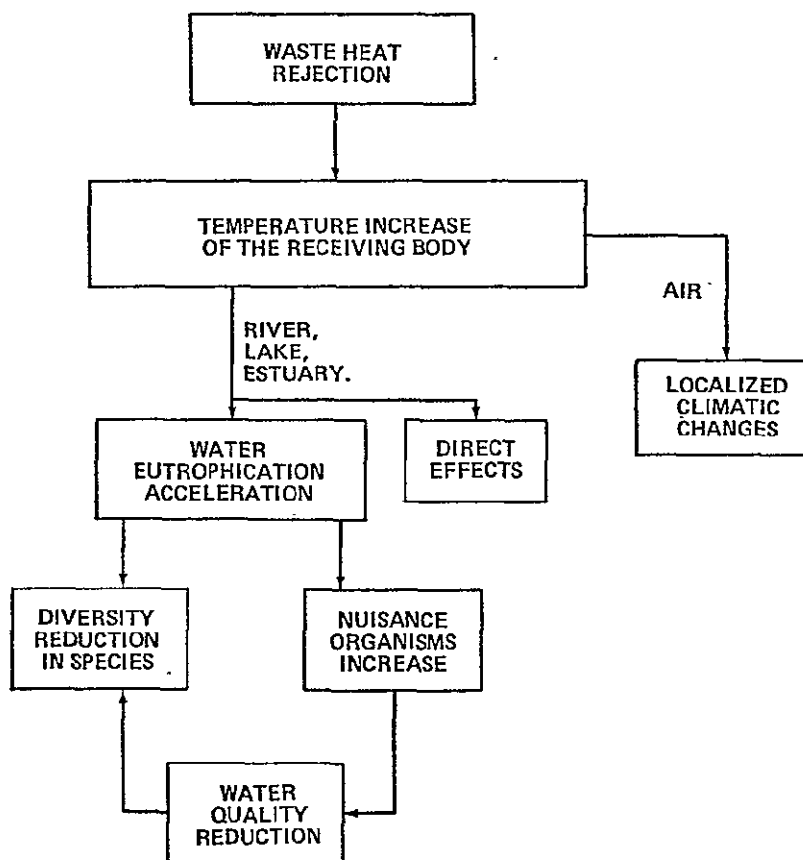
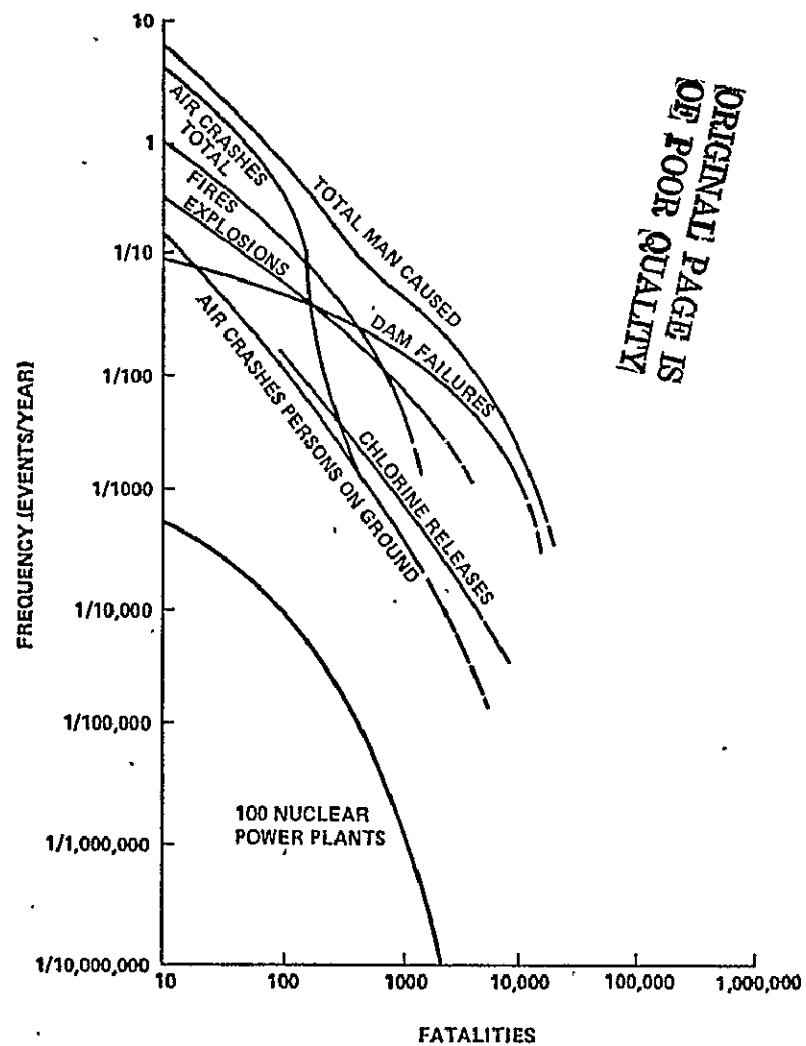
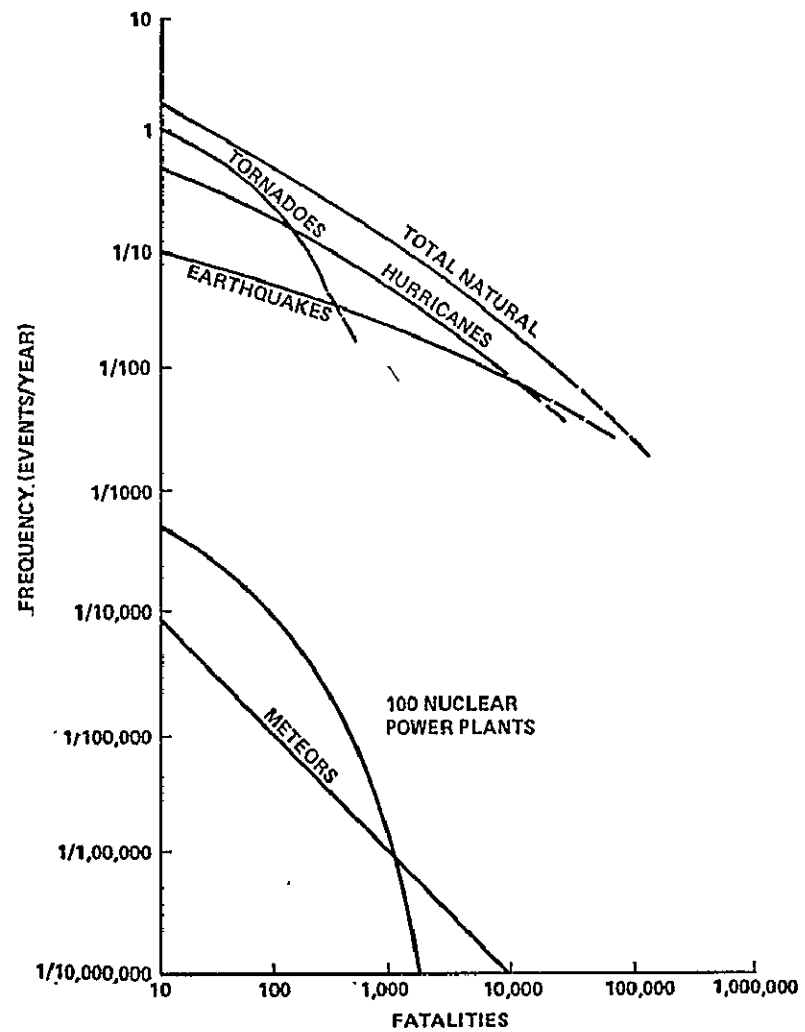


FIGURE J.2.2-8 IMPACTS FROM WASTE HEAT REJECTION



FREQUENCY OF FATALITIES DUE TO MAN-CAUSED EVENTS  
(AEC-74-4)

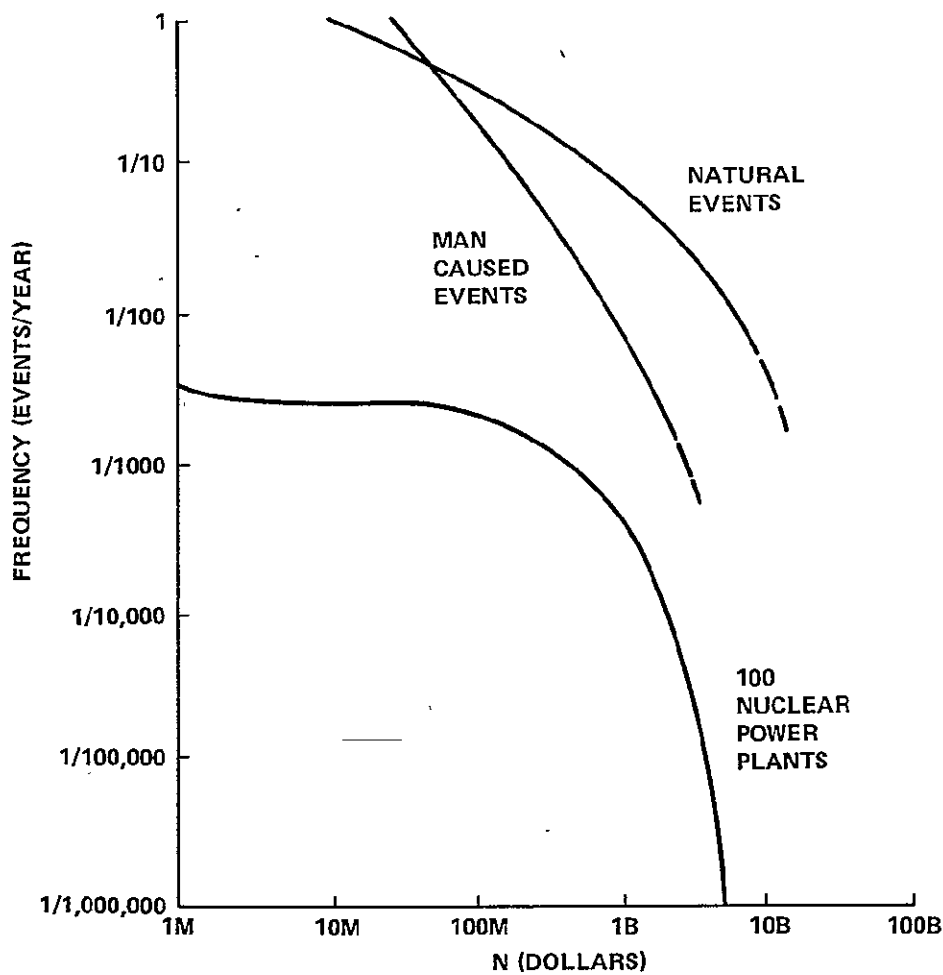
FIGURE J.2.2-9



FREQUENCY OF FATALITIES DUE TO NATURAL EVENTS  
(AEC 74-4)

FIGURE J.2.2-10





FREQUENCY OF PROPERTY DAMAGES DUE TO NATURAL AND  
MAN-CAUSED EVENTS (AEC-74-4)

FIGURE J.2.2-11

The results indicate that non-nuclear events are about 10,000 times more likely to produce large accidents than nuclear plants. Also, nuclear plants are about 100 to 1000 times less likely to cause comparable large dollar value accidents than other sources. Property damage includes 1) cost of temporarily moving people away from contaminated areas, 2) denial of use of real property during reactivity clean up, and 3) assuring no exposure of the public to the radioactivity in food and water supplies.

In addition to fatalities and property damage, a number of other health effects can be caused by nuclear accidents. These include injuries and long term health effects such as cancers, genetic effects and thyroid gland illness. The injuries expected in potential accidents would be about twice as large as the fatalities shown in Figures J.2.2-9 and J.2.2-10; however, such injuries would be insignificant compared to the 8 million injuries caused annually by other accidents.

The most likely core melt accident would occur on the average of one every 17,000 years per nuclear plant. The size of the consequences of such an accident are illustrated in Table J.2.2-15. A comparison of the consequences of various types of accidents is presented in Table J.2.2-16.

It is possible for a core melt accident to release enough radioactivity so that some fatalities might occur within a short time (a few weeks) after the accident. Other people may be exposed to radiation levels which would produce observable effects which would require medical attention but from which they would recover completely. In addition, some people may receive even lower exposures which produce no noticeable effects but may increase the incidence of certain diseases over a period of many years. This last situation is illustrated in Table J.2.2-17 for two accident conditions. Note that the effects are difficult to notice because the increases are predicted to be much smaller than the normal incident rate of these diseases.

Comparison of mortality rates in three power plant types is given in Table J.2.2-18.

#### Impacts from Diversion of Nuclear Materials

The impacts resulting from the theft or diversion of some kinds of nuclear materials depend upon the use of the materials as an explosive nuclear weapon, a biological poison or as a radioactive source.

It takes approximately 34 pounds of highly enriched uranium, above 90%, to make a crude bomb. At enrichments above 20%, the uranium can be made to explode. However, the amount of material needed would be large and the explosive force relatively low [Buchanan-74]. Highly enriched uranium is one of the fuel materials used in HTGR's. The low enrichment level, about 3%, in the fuel of a LWR makes it a non-nuclear explosive material.

TABLE J 2.2-15. CONSEQUENCES OF THE MOST LIKELY CORE MELT ACCIDENT

	<u>Consequences</u>
Fatalities	<1
Injuries	<1
Latent Fatalities	<1
Thyroid Nodules	~4
Genetic Defects	<1
Property Damage*	\$100,000

\*This does not include damage that might occur to the plant.

TABLE J.2.2-16. ANNUAL FATALITIES AND INJURIES EXPECTED AMONG THE 15 MILLION PEOPLE LIVING WITHIN 20 MILES OF U.S. REACTOR SITES

<u>Accident Type</u>	<u>Fatalities</u>	<u>Injuries</u>
Automobile	4,200	375,000
Falls	1,500	75,000
Fire	560	22,000
Electrocution	90	--
Lightning	8	--
Reactors (100 plants)	0.3	

TABLE J.2.2-17. MAGNITUDE OF LATENT HEALTH EFFECTS EXPECTED IN A 20 YEAR PERIOD FOR AN ACCIDENT THAT PRODUCES 100 FATALITIES

Effect	Chance Per Plant Per Year		Normal* Incidence Rate
	One in 17,000	One in 1,000,000	
Latent Cancers	< 1	450	64,000
Thyroid Illness	4	12,000	20,000
Genetic Effects	< 1	450	100,000

\*This is the normal incidence that would be expected for people in the vicinity of any one reactor.

TABLE J.2.2-18. PREDICTED MORTALITY RATES FOR ELECTRIC POWER PLANTS

<u>POWER PLANT TYPE</u>	<u>MORTALITY RATE (FATALITIES/MILLION PEOPLE/YEAR)</u>
Coal-Fired	300 <sup>(1)</sup>
Oil-Fired	250 <sup>(1)</sup>
Nuclear Fueled	< 1 <sup>(2)</sup>

(1) [Forbes-74]

(2) [AEC-74-4]

The amount of plutonium, recovered from the spent fuel reprocessing (mainly of LWRs), needed to manufacture a nuclear explosive is about 16 pounds. The future growth of the nuclear energy industry will depend to a large extent on the recycling of the plutonium for use in LWRs and the breeder reactors. Thus, relatively large amounts of plutonium will be circulating in the nuclear fuel cycle. The potential of plutonium as weapons grade material and as a high radio-toxic biological poison, presents a dangerous situation to national security and public safety.

The most vulnerable sectors for diversion of nuclear materials are considered to be the areas of fuel reprocessing, fuel fabrication and transportation.

Spent fuel elements as well as nuclear waste materials could be subjected to a conventional explosion by terrorist actions during the transportation of such materials.

Another area of concern is the sabotage of facilities in the nuclear fuel cycle. In particular, nuclear power plants and fuel reprocessing facilities would be the most probable targets due to the added impact of radioactive releases. In the case of a nuclear plant, the damage produced by reactor sabotage is comparable to the consequences resulting from some of the accidents postulated in the safety analysis of the plant.

Plutonium toxicity has been singled out as a very unique property. However, there are natural and industrial materials capable of producing health impacts as large as those attributed to plutonium. No proper training or special capability are needed to handle some of these materials.

Damages caused by sabotage of a nuclear facility or of a shipment of nuclear material, resulting in radioactive contamination of the surrounding area, would be covered by the Price-Anderson insurance and indemnity agreements. However, theft of nuclear material followed by damage resulting from its misuse at a location other than a power plant site or from the shipment on a planned transportation route probably would not be covered [NI-75-1].

#### Impacts From Waste Heat Disposal

There are limits on the convertibility of heat into other energy forms. In all machines in which heat is converted to work, a substantial portion of the heat input is invariably discharged to the environment. This appears to be a fact of nature with no exceptions known or expected.

Although in many situations electrical energy can be utilized more effectively than other forms, there is a considerable heat waste in the generation of electrical power. Heat from the combustion of fossil fuel in a boiler, or from the fission of nuclear fuel in a reactor, is used to produce steam at high temperature and pressure. The steam, in turn, drives a turbine connected to a generator. After going through the turbine and producing a certain amount of work, the steam is converted back into water in a condenser.

The process of steam condensation is accomplished by passing large amounts of cooling water from a water supply system through the condenser of a steam electric generating plant. The water supply may be in the form of a river, lake, estuary or ocean waters. In this process, heat is added to the cooling water, which when returned to the supply body is the origin of the thermal effects on the environment.

The simplest and most commonly employed method for provision of cooling water to the condenser in a power plant is the single-pass or once-through system. Water is withdrawn from an available source such as a river, lake, bay, estuary or ocean, and pumped through the condenser. After passing through the condenser, it is discharged back into the source. The points of intake and discharge are separated so that there is a minimal recirculation of water which has been through the system. The rate of water pumping through the condenser depends on the size of the plant and on the water temperature increase expected. A 1000 MW plant would require about 500,000 gallons per minute for about a 20°F temperature rise of the water.

In some cases, to avoid thermal discharges to public water bodies or when there is no water capacity to cool the large power plants being built today, a cooling pond or artificial lake is employed. Cooling of the discharge water occurs through evaporative cooling, direct transfer of heat to the air, and radiation. The pond or lake must receive make-up water to compensate for the evaporation loss. The cooling pond is generally designed to function as an adjunct of the power plant and is seldom used for any other function.

When new power plant sites have water supplies inadequate for once-through cooling or where recourse to a cooling pond or artificial lake is not a viable course of action, electric utilities are turning to cooling towers. The most common types of cooling towers are the evaporative or wet type, whether mechanical or natural draft. In wet cooling towers, the water is brought in direct contact with a flow of air, and the heat is dissipated to the atmosphere, principally by evaporation of some of the cooling water. Make-up water is added to replace evaporative losses.

Where addition of water to the atmosphere or the consumptive loss of water is unacceptable, the dry type cooling towers might be installed. In this method of cooling, water circulates inside the tubes of a radiator and air is blown by fans past the outside of the tubes to remove the heat from the water by a combination of conduction and convection heat transfer. No water is lost since it circulates in a close loop without contacting the cooling air.

### Atmospheric Impacts

In all the power plant cooling methods discussed above, the waste heat is eventually transferred to the atmosphere. In estimating the impact of the rejected heat on the weather conditions, both the surface area over which heat is transferred and the dispersion characteristics of the atmosphere are important. It is the concentration of large amounts of waste heat in a relatively small region that will tax the capability of the atmosphere to assimilate the heat locally [Rotty-74-1]. On the other hand, when the heat is dispersed over a large area, the thermal impact is minimized. Table J.2.2-19 illustrates the effect of localized heat sources ("urban heat islands") on the climate of cities. Other effects not included in Table J.2.2-20 are less snowfall due to melting in going through a warmer urban atmosphere and longer frost-free growing season.

The clustering of electric generating plants within relatively small geographical areas can have changes in climatic conditions similar to the city heat island. The flux heat density provides an indication of the potential impact of a power plant as a heat island. In most cases, the heat rejected to the atmosphere is much more concentrated than that released from cities. In fact, this is the case for power plants using cooling towers. Thus, greater impacts than those experienced in city atmospheres can result. Comparative heat flux density for various sources is given in Table J.2.2-20.

Meteorological consequences due to large addition of heat to the atmosphere have been recorded. Table J.2.2-21 summarizes the characteristics of the particular cases and the atmospheric impacts. Note that in the case of a large cooling tower, the energy flux density exceeds that of the French Meteotron (an array of oil burners). However, the meteorological impact of large quantities of heat added to the atmosphere over small areas cannot be specified at the present time. It is evident that the heat releases from large power plants (especially nuclear) are comparable with the heat discharges from other events that have caused perturbations and climate changes of appreciable magnitude. In order to minimize the impacts, heat should be rejected over as large an area as possible. In this respect,

TABLE J.2.2-19 CLIMATIC CHANGES PRODUCED BY CITIES (after Landsberg, 1962)  
[CROTTY-74-11]

Element	Compared with rural environs
Temperature	
Annual mean	1.0 to 1.5°F higher
Winter minima	2.0 to 3.0°F higher
Relative humidity	
Annual mean	6 percent lower
Winter	2 percent lower
Summer	8 percent lower
Dust particles	10 times more
Cloudiness	
Clouds	5 to 10 percent more
Fog, winter	100 percent more
Fog, summer	30 percent more
Radiation	
Total on horizontal surface	15 to 20 percent less
Ultraviolet, winter	30 percent less
Ultraviolet, summer	5 percent less
Wind speed	
Annual mean	20 to 30 percent less
Extreme gusts	10 to 20 percent less
Calms	5 to 20 percent more
Precipitation	
Amounts	5 to 10 percent more
Days with > 0.2 inch	10 percent more

C. S.



TABLE J.2.2-20. COMPARATIVE HEAT FLUX DENSITY FOR VARIOUS SOURCES (LARGE AREAS)  
CROTTY-74-21

	<u>Area</u> Km <sup>2</sup>	<u>Heat Flux Density</u> W/m <sup>2</sup>	<u>Fraction of Solar Flux at Ground</u>
Solar Constant		1352	
Average Solar Energy Trapped in Earth Atmosphere System (24 hour average)	5.1 x 10 <sup>8</sup>	246	
Average Solar Energy Flux at ground	5.1 x 10 <sup>8</sup>	160	1.00
<hr/>			
Anthropogenic Heat from Cities:			
Manhattan, New York City	59.8	630	3.94
Moscow	878	127	.79
Washington, D. C.	173	44	.28
Los Angeles Basin	10,000	7.5	.05
Boston-Washington Metropolitan Area - (Projection for 2000 AD)	31,200	36	.23
Sheffield, England	48	19.2	.12
<hr/>			
Waste Heat from Power Plants:			
Dresden and Braidwood (over area for city of 1 million people)	230	35.3	.22
Dresden, LaSalle, Braidwood (area sufficient to include all three)	634	19.5	.12
Summit, Salem, Hope Creek (12 mi. x 5 mi.)	155	73.8	.46
Peach Bottom, Fulton, Summit, Salem, Hope Creek, Bainbridge, Conowingo (50 mi. x 10 mi.)	1,294	22.1	.14

TABLE J.2.2-21. EFFECTS OF LARGE HEAT ADDITIONS TO THE ATMOSPHERE CROTTY-74-23

Phenomenon	Energy Rate (Mw)	Area (Km <sup>2</sup> )	Energy Flux Density	Meteorological Consequences
a. Large brush fire	100,000	50 <sup>+</sup>	2000	(Relatively small energy flux rate, very large area) Cumulus cloud reaching to a height of 6 km formed over 1/10 area of fire. Convergence of winds into a fire area
b. Forest Fire Whirlwind				Typical whirlwind: Central tube visible by whirling smoke and debris. Diameters few feet to several hundred feet. Heights few feet to 4,000 ft. Debris picked up - logs up to 30 inches in diameter, 30 ft. long.
c. WWII Fire Storm		12		Turbulent column of heated air 2 1/2 miles in diameter. Fed at base by inrush of surface air. One and a half miles from fire, wind speeds increased from 11 to 33 mph. Trees 3 feet in diameter were uprooted.
d. Fire at Hiroshima				(10-12 hours after A-bomb). "The wind grew stronger, and suddenly - probably because of the tremendous convection set up by the blazing city - a whirlwind ripped through the park. Huge trees crashed down; small ones were uprooted and flew into the air. Higher, a wild array of flat things revolved in the twisting funnel..." The vortex moved out onto the river, where it sucked up a water spout and eventually spent itself.
e. Surtsey Volcano	100,000	<1	100,000	Permanent cloud extending to heights of 5 km to 9 km. Continuous sharp thunder and lightning, visible 115 km away. (Phenomenon probably peculiar to volcano cloud with many small ash particles). Waterspouts resulting from indraft at cloud base, caused by rising buoyant cloud.
f. Surtsey Volcano	200,000	1	200,000	Whirlwinds (waterspouts and tornadoes) are the rule rather than the exception. More often than not there is at least one vortex downwind. Short inverted cones, or long, sinuous horizontal vortices that curve back up into the cloud, and intense vortices that extend to the ocean surface.
g. French Meteotron	700	.0032	219,000	"artificial thunderstorms, even tornadoes, many cumulus clouds...substantial downpour. Dust devils.
h. Meteotron	350	.016	22,400	15 minutes after starting the burners, observers saw a whirl 40 meters in diameter...whirlwind so strong burner flames were inclined to 45°.
i. Single large cooling tower	2,250	.0046	484,000	Unknown
j. Array of large cooling towers (Nucl. Park)	72,000	4	18,000	Unknown

ORIGINAL PAGE IS  
OF POOR QUALITY

once-through cooling has a major advantage over the other cooling methods. Although cooling lakes and ponds could be placed in the same category as once-through cooling, their impacts are usually larger since economics dictate that as little land as possible should be devoted for these methods.

Other atmospheric impacts include fogging, icing, drift and vapor plumes for cooling ponds, lakes and cooling towers.

### Ecological Impacts

Some of the ecological impacts associated with temperatures increases due to waste heat rejection to various water bodies are shown in Figure J.2.2-8.

Water eutrophication is a natural phenomena in water bodies. It is more noticeable in lakes and reservoirs which do not have a large flow-through. Most lakes gradually become more fertile with the passage of time. This process, known as eutrophication, results from the accumulation of organic wastes and the addition of inorganic nutrients such as nitrogen and phosphorus from the surrounding watershed. [Brown-71] Man has accelerated this process by addition of nutrients in sewage waste. Thermal discharges may further accelerate the process by increasing the temperature of the upper layers of the water body, promoting, for example, algae growth rate. Eutrophication eventually results in lower water quality through a loss in oxygen available for fish that inhabit the lower levels of the water.

When an ecosystem is placed under stress, it leads to reduction in species diversity. The species that are more tolerant to stress (temperature increases) survive. Usually, they are the noxious ones (blue-green algae). [Brown-71]

Discharges of heated effluent to rivers that host species of fish which migrate to spawn may produce a thermal block to the movements of such species, unless care is taken to confine the area of temperature addition to a portion of the river.

Thermal effects of a power station may appear even though the temperature of the water body after mixing is not raised materially. Water which passes through the condenser is heated considerably in a very short time interval. Some of the dissolved oxygen is lost from the water as it is heated. The solubility of oxygen in water decreases with increasing temperature.

Free floating organisms are of great importance in the aquatic life of estuarine waters. Studies have shown that such organisms, which are entrained in the water because they are small and free-floating, do not survive passage through the condenser very well.

The factors involved in an analysis of the effects of thermal loading of a particular aquatic system are very complex, and no single index, such as change in fish catch, can provide an adequate testimony to the effects of a particular installation.

#### Impacts From Nuclear Shipment Accidents

The operation of nuclear reactors will usually require the transportation of three different types of materials to and from reactor facilities. Unirradiated nuclear reactor fuel elements are transported from fuel fabricators to the reactor. Irradiated fuel elements and nuclear waste are shipped from reactor facilities to fuel reprocessing plants and to disposal sites. Also, the radioactive products of the spent-fuel reprocessing plants consist primarily of recycled nuclear fuel materials shipped to fuel fabricators or processors and both high and low-level waste shipped to storage or disposal sites.

The Department of Transportation (DOT) has estimated that there are nearly one million shipments of nuclear materials each year. About 95% of the shipments involve small quantities of nuclear isotopes for use in industry, medicine, agriculture, and education. By comparison, the total number of shipments of nuclear materials to and from nuclear power plants in 1971 probably numbered only a few thousand [Brobst-74].

Protection of the public and transportation workers from radiation, during shipments of nuclear fuel and waste, is achieved by limitations on both the contents and the package design. Because nuclear shipments move in routine commerce and on conventional transportation equipment, they are subject to normal transportation accident environments.

A highly developed and sophisticated system of protection has evolved for the transportation of nuclear materials. This system is based on a simple principle: if the package contains enough radioactivity to present a significant risk of injury or large property loss if released, then the package (Type B) must be designed to retain its contents during severe transportation accidents. Lesser quantities of radioactive materials do not require as much protection, but still must be packaged in high quality packaging (Type A) designed to withstand less severe transportation accidents [Brobst-74].

The transportation of nuclear materials is subject to regulation by both DOT and the NRC.

Nuclear wastes which are shipped around the country to various processing, storage, or burial sites fall into four general categories: (a) low-level wastes, (b) high-level wastes, (c) alpha wastes, and (d) other waste.

Low-level wastes contain such low concentrations or quantities of radioactivity that they do not present any significant environmental hazards. High-level wastes are solidified wastes from the reprocessing of highly irradiated nuclear reactor fuels. The waste is inert, immobile, solid material which is nonexplosive, non-combustible, and cannot turn to gaseous form and become airborne. Alpha wastes usually consist of materials which are contaminated with alpha radiation emitters such as plutonium. Other wastes are predominantly of the beta-gamma type, such as the irradiated reactor structural components.

Shipments of nuclear material during 1985 will be nation-wide, but will predominantly be in the eastern part of the United States. The number of shipments and quantities of waste are given in Table J.2.2-14.

For truck accidents, the injury rate is about 0.65 injuries per accident and the death rate is about 0.03 deaths per accident. The accident rate for shipments is about 1.7 accidents per million truck miles and about 0.53 accidents per million truck miles for hazardous materials shipment [DOT-74]. The accident rate for rail accidents is about 1.5 accidents per million car miles. There are about 2.4 injuries per accident and about 0.26 deaths per accident. These statistics are for 1972 [DOT-73].

To date there have been no injuries or deaths of radiological nature due to the transportation of nuclear materials. There have been a few cases of truck drivers being killed or injured as a result of a collision or overturn of vehicles carrying nuclear materials. In none of these accidents, however, was there any release of nuclear materials from Type B packages.

In recent years, DOT has recorded an average of 8000 to 9000 incidents per year involving the transportation of hazardous materials in which 15 to 20 involve nuclear materials [Brobst-74]. Almost all of these incidents involved Type A packages. In about two-thirds of these cases, there was no nuclear material released from the packages. In a few percent of the cases, there was significant contamination requiring cleanup. The cleanup costs ran into the thousands of dollars.

In a 1972 study [AEC-72-1], the Atomic Energy Commission (now NRC) estimated that under normal conditions of spent fuel and radioactive waste shipment, each truck driver could receive a radiation dose of as much as 30 mrem per shipment. A few members of the general public could receive as much as 1 mrem per shipment. By comparison, the average annual exposure from other sources (such as natural radioactivity of the earth, medical exposures, and cosmic radiation) is about 150 mrem.

Based on DOT accident statistics, we can calculate how many accidents involving nuclear shipments might be expected each year. Assuming 100,000 truck-miles per year of transportation for each nuclear power plant and with 190 such plants by 1985, one can expect about 10 accidents per year involving nuclear reactor shipments. Those accidents will produce 24 injuries per year, and about 3 deaths per year. In the case of rail shipments, assuming 15,000 railcar miles per year per reactor, there might be about 5 accidents with 11 injuries and 11 deaths per year. These deaths and injuries would not be related to the nuclear nature of the shipments.

The vast majority of accidents involving nuclear shipments will result in no release of nuclear materials, or injury or death due to radiation. According to another AEC study, only about one transportation accident in every two million could be violent enough to cause a large enough cask break to present a serious public hazard.

#### Impacts From High-Level Waste Management

High-level nuclear waste originates when fuel discharged from a nuclear reactor is reprocessed to recover the unused fuel and the fissionable isotopes (plutonium) produced. Chemical dissolution and treatment of the spent fuel yields an acidic aqueous solution. Typical constituents of the high-level waste (solvent extraction method) are shown in Table J.2.2-22 [AEC-74-1]. Estimated quantities of high-level waste for 1985 are included in Table J.2.2-14.

Burial in a deep geologic formation, such as salt, would free man from the burden of continuing surveillance and control. The potential advantage of salt over other rock types as a medium for waste disposal of high-level radioactive waste is the stability shown over many several hundred of millions of years. Being soluble in water, the very presence of salt in massive bodies beneath the ground attest to the fact that salt has, in general, been isolated from circulating ground waters for this period of time. For any form of geologic storage, it is only through transport in ground water that buried solidified wastes could come into contact with man's environment [AEC-74-1].

Interim storage for periods of up to 30 years indicates a cost of about 0.015 mill/kwhe. For a 50-year storage period, a cost of approximately 0.025 mill/kwhe seems reasonable. [Kubo-73]

Table J.2.2-22 indicates that the total amount of fission products (not including uranium) is approximately 30-kg per metric ton of fuel. Assuming a fuel reprocessing load of 23 metric tons/year/GWe, (Table J.2.2-14) this gives about 690 Kg of high level waste per year per GWe. Using a density of 1 gram per cc for solidified high-level waste (a conservative value), it [AEC-74-1] yields a volume of 690 liters/year/GWe.

TABLE J.2.2-22. TYPICAL MATERIALS IN HI-LEVEL LIQUID WASTE [AEC-74-11]

	Material (b)	Grams/MT from Reactor Type (a)		
		LWR (c)	HTGR (d)	LMFBR (e)
<u>Reprocessing Chemicals</u>	Hydrogen	400	3,800	1,300
	Iron	1,100	1,500	26,200
	Nickel	100	400	3,300
	Chromium	200	300	6,900
	Silicon	--	200	--
	Lithium	--	200	--
	Boron	--	1,000	--
	Molybdenum	--	40	--
	Aluminum	--	6,400	--
	Copper	--	40	--
	Borate	--	--	98,000
	Nitrate	65,800	435,000	244,000
	Phosphate	900	--	--
	Sulfate	--	1,100	--
	Fluoride	--	1,900	--
	Sub-total	67,500	452,000	380,000
<u>Fuel Product Losses (f,g)</u>	Uranium	4,800	250	4,300
	Thorium	--	4,200	--
	Plutonium	40	1,000	500
	Sub-total	4,840	5,450	4,800
<u>Transuranic Elements (g)</u>	Neptunium	480	1,400	260
	Americium	140	30	1,250
	Curium	40	10	50
	Sub-total	660	1,440	1,560
Other Actinides (g)		<0.001	20	<0.001
Total Fission Products (h)		28,800	79,400	33,000
TOTAL		103,000	538,000	419,000

a. Water content is not shown; all quantities are rounded.

b. Most constituents are present in soluble, ionic form.

c. U-235 enriched PWR, using 378 liters of aqueous waste per metric ton, 33000 MWd/MT exposure. (Integrated reactor power is expressed in megawatt-days [MWd] per unit of fuel in metric tons [MT].)

d. Combined waste from separate reprocessing of "fresh" fuel and fertile particles, using 3,785 liters of aqueous waste per metric ton, 94,200 MWd/MT exposure.

e. Mixed core and blanket, with boron as soluble poison, 10% of cladding dissolved, 1,249 liters per metric ton, 37,100 MWd/MT average exposure.

f. 0.5% product loss to waste.

g. At time of reprocessing.

h. Volatile fission products (tritium, noble gases, iodine and bromine) excluded.

ORIGINAL PAGE IS  
OF POOR QUALITY

Based on approximately 1060 GWe-years (from Figure J.2.2-1), the amount of solidified high-level waste that will accumulate between 1975 and 1985 is around 24,000 cubic feet. Considering the relatively small amounts of high level waste that are being generated presently, the wastes can be stored at individual power plants until a repository becomes available.

### Technological Impacts

The technology for providing the nuclear fuel cycle requirements is available. Improvements in the gaseous diffusion process will increase the capacity for fuel enrichment after the Cascade Up-grading Program and Cascade Improvement Program are implemented. The introduction of the gas centrifuge will constitute a technological asset since it is less energy intensive than the gaseous diffusion process.

The decision to recycle plutonium has been postponed until 1978. If plutonium recycle is favorably considered, then greater safety must be emphasized in the fuel cycle. This is due to public health and safety implications resulting from plutonium diversion or theft.

Long storage of high-level nuclear waste is under research and development and an acceptable disposal method is not expected to be available before 1995.

Some nuclear reactors of the boiling water type have been experiencing difficulties with respect to vibrations in the reactor core. As a result, their power level has been degraded to 50 percent of the maximum.

### Social/Political Impacts

Nuclear energy industry growth would be unlikely in the case of a serious nuclear accident. Social pressure, at a higher level than now exists, could create a moratorium on nuclear power plant construction. The provisions of the Price-Anderson Act, regarding insurance and indemnity agreements by the Federal government to cover damages by a nuclear accident (\$500 million), may not be sufficient to cover medical expenses, loss of income and the various damages which might occur. In addition, there are presently no provisions for damages produced by misuse of nuclear materials at locations other than nuclear plants and planned transportation routes.

Some of the proposed legislation to regulate the nuclear industry may have a negative impact if approved. For example, the Nuclear Energy Reappraisal Act (HR 4971) terminates the granting of construction licenses for nuclear power plants pending action by Congress after a five-year study by the Office of Technology Assessment. This bill is still in committee. [NN-75, 55]



The public opinion is highly polarized with respect to the issues concerning nuclear power. The intervening groups have effectively challenged the construction of power plants at the local and federal level. As a result, construction schedules in many plants have been delayed.

#### Pending Legislation (see also Appendix N)

The future of the nuclear electric industry depends to a large extent on the public attitude toward this source of energy. In spite of the fact that the nuclear industry is one of the most regulated activities in this country, a lot of issues are still being debated at the local and national level. Legislation has been proposed to expedite the growth of nuclear power while other proposals tend to counteract the former by limiting various activities and programs which are vital to the future of this industry.

Major nuclear legislation of the 94th U.S. Congress which was not considered in Chapter 10 is presented in this appendix. These are summarized and listed below [NN-75].

<u>Bill Number</u>	<u>Description</u>
H.R. 2650 (S. 594)	Energy Independence Act of 1975. Alters regulatory practices related to electric utilities, and early site work under some circumstances.
H.R. 3618, H.R. 6394	Plutonium Recovery Control Act of 1975. Prevents licensing of power reactors using recycled plutonium pending a three-year study by the Office of Technology Assessment (OTA).
S. 1197	Plutonium Recovery Control Act of 1975. This is similar to H.R. 3618 but does not specify a time limit for the OTA study.
H.R. 3995	Nuclear Facility Licensing Act. Provides for early and separate site reviews and licensing, allows combined construction/operating permit for pre-approved plants for licensed sites, allows technical aid to intervenors, ends mandatory hearing for construction permit. This is nearly identical to S. 1717 (H.R. 7002)

<u>Bill Number</u>	<u>Description</u>
S. 1439	Export Reorganization Act of 1975. Requires NRC to certify that a country importing nuclear facilities and materials from the U.S. has safeguards at least comparable to those of NRC.
S. 166'	Public Intervenors Assistance Act. Provides public funding to intervenors who demonstrate (to NRC) both a financial need and a contribution to the nuclear licensing proceeding.

All these bills are still presently under committee consideration.

### J.2.3 IMPROVE OPERATIONS OF PUBLIC UTILITIES

The technical and economic future of the electrical utilities will be addressed.

#### J.2.3.1 THE TECHNOLOGY

In a summary of the specific types, technical requirements and cost of installing equipment associated with direct or indirect management of electric demand are presented. The equipment represents options whose preliminary evaluation indicates a need for further study. The equipment falls into the following four categories:

Energy Storage Equipment -- Such equipment may be used with either direct or indirect methods of load management.

Equipment Permitting Off-peak Operations Without Energy Storage -- In continuous operations, additional production equipment would usually be needed.

Utility Control-Related Equipment -- Such equipment is needed only with direct methods of load management. It would normally be installed by the utility expert, in some cases, for rewiring needed on the customer side of the meter to isolate circuits being controlled from uncontrolled circuits.

Revenue Metering Equipment -- Revenue metering equipment capable of distinguishing between KWH's consumed on-peak and KWH's consumed off-peak.

Those techniques related to the utility industry directly are discussed in this section. Those related directly to the sectors are included below.

Electric utility experience with pumped hydro storage has demonstrated that large-scale storage of energy can result in significant operating and economic advantages for electric power systems. These advantages, and the potential for conservation of scarce, high-quality fossil fuels, have generated much interest. They appear to broaden the applicability and increase the usefulness of energy storage (see Figure J.2.3.1-1).

Sharply increased fuel prices create a heavy penalty for older, inefficient equipment. Natural gas as well as high quality distillate fuels are becoming less available and more costly. Thus, incentives are growing rapidly to use base load plants to also provide the electric energy now generated by peaking and intermediate equipment -- an approach which requires storage of off-peak energy generated by base load plants. The use of energy storage in "peak shaving" is illustrated in Figure J.2.3.1-2.

Table J.2.3.1-1 illustrates the characteristics of various generating and storage systems. [EULMC-74] The probable minimum economic size is expressed in MWH, the approximate capital cost, in dollars/KW, the potential efficiency and the energy/unit volume in KWH/m<sup>3</sup> are depicted for six main types of storage systems. These are the underground pumped hydro, compressed air storage, batteries, hydrogen storage, superconducting magnets, and super-flywheels. It can be seen that in/out storage efficiencies vary from 45% to 85%. Table J.2.3.1-2 provides a comparison of these storage concepts based on a few solution criteria. [EULMC-74] It is important to note that the storage systems are capable of conserving energy through the substitution of nuclear fuel and coal for fuels such as distillates used for combustion turbines. Moreover, combustion turbines are less efficient than an efficient storage device storing energy from a highly efficient base load. The interested reader is referred to [Kalhammer-74] on the potential of most of the above mentioned storage systems in electric utility systems.

The three most attractive storage technologies are pumped hydro, compressed air, and primary batteries.

Underground pumped hydro has been considered in combination with the storage in caverns of storm drainage waters of certain cities. The concept requires an upper reservoir for the pumped storage as well as the underground reservoir to receive the storm waters. Benefits of the concept include the anti-flooding provision of drainage into the lower reservoir, conservation of flood waters, location of the pumped storage plant practically at the load center, and possible use of the above ground reservoir for recreational purposes (if fluctuation of its level were sufficiently minimal.) The required R and D mainly would be [FPG-74] investigation of excavation of underground caverns, particularly with respect to the geological and seismic conditions at sites for cities considering this concept.

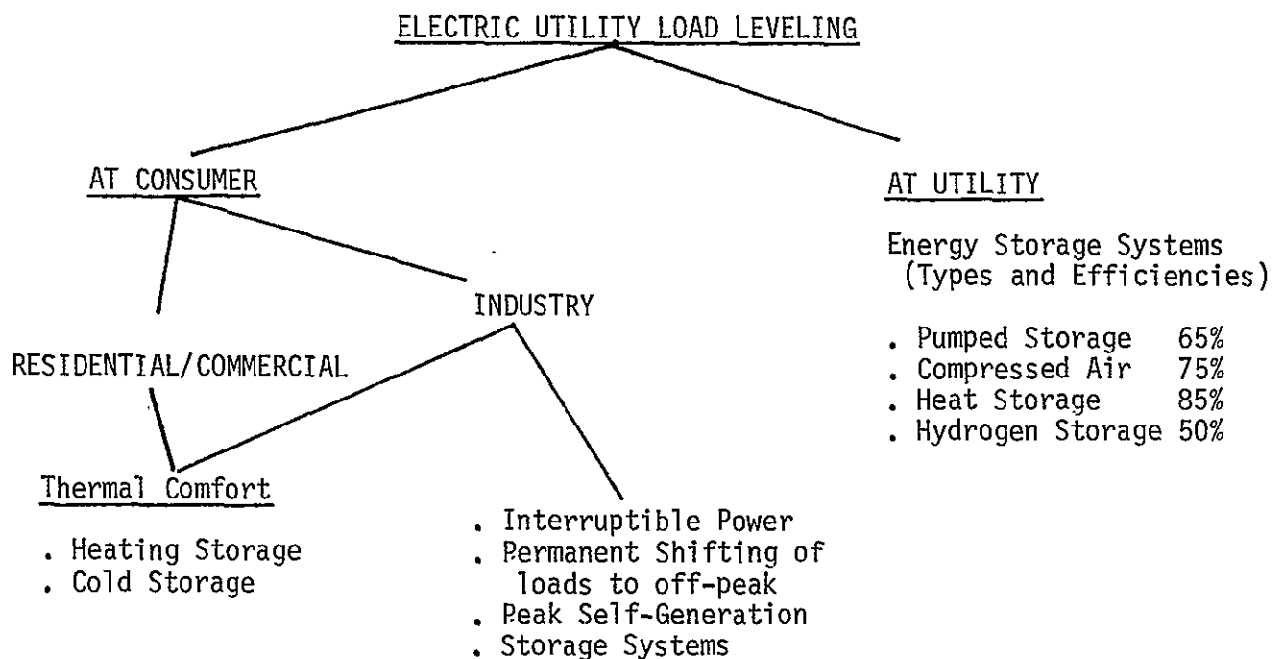


FIGURE J.2.3.1-1 UTILITY ENERGY STORAGE

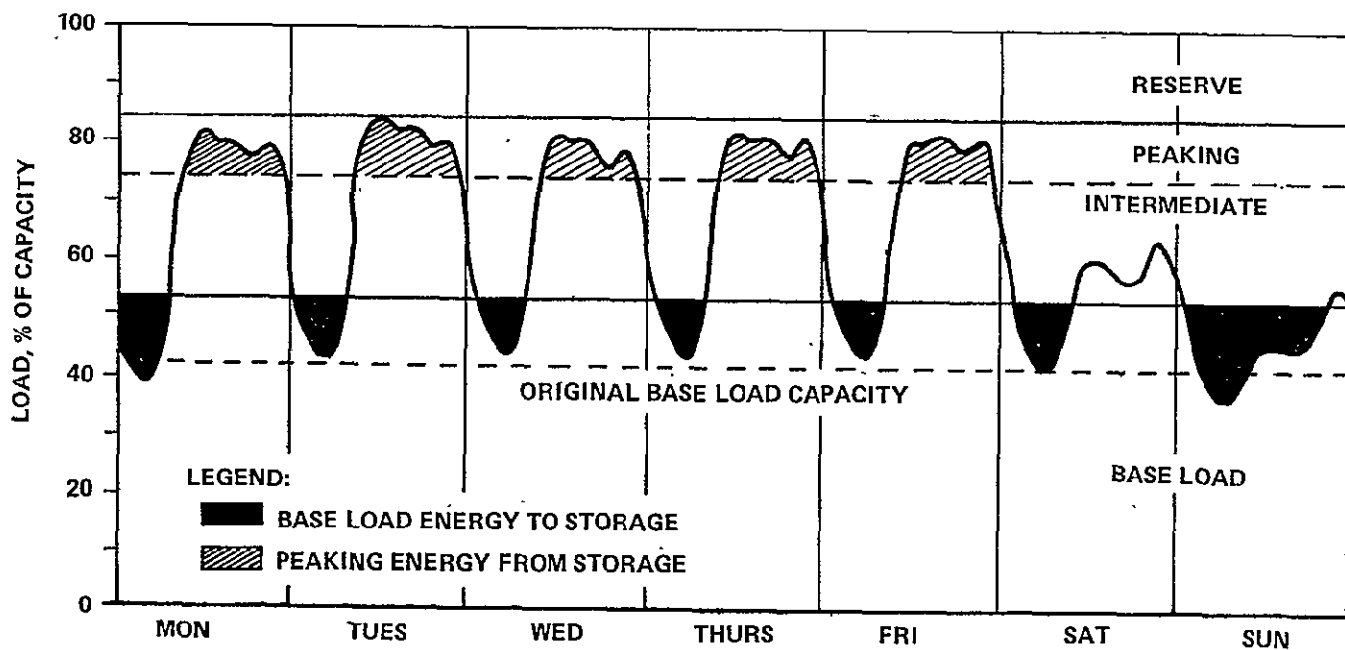


FIGURE J.2.3.1-2. USING ENERGY STORAGE IN GENERATION MIX

TABLE J.2.3.1-1. CHARACTERISTICS OF VARIOUS GENERATING AND STORAGE SYSTEMS, [EULMC-74]

TYPE	PROBABLE MINIMUM ECONOMIC SIZE (MWh)	APPROXIMATE CAPITAL COST (\$ KW)	POTENTIAL EFFICIENCY %	LIKELY ENERGY/ UNIT VOLUME (Kwh/m <sup>3</sup> )	EXPECTED LIFE (years)
1. Underground Pumped Hydro	10,000	200	65	2	50
2. Compressed Air Storage	200	230	45	4	20
3. Batteries	10	150	75	250	20
4. Hydrogen Storage	10	300	50		30
5. Superconducting Magnets	10,000	700	85	20	30
6. Superflywheel	10	400	85	35	30
7. Combustion Turbine	50 MW	120	24		20
8. Steam Cycle Plant	500 MW	350	37		30

TABLE J.2.3.1-2. RELATIVE MERITS OF STORAGE CONCEPTS (0 to 3 WITH 3 THE HIGHEST), [EULMC-74]

CRITERIA	UNDERGROUND PUMPED HYDRO	COMPRESSED AIR STORAGE	BATTERIES	HYDROGEN STORAGE	SUPER- CONDUCTING MAGNETS	SUPER- FLYWHEELS
Economic Feasibility	3	3	3	1	0	2
Environmental Compatibility	1	1	3	3	3	3
Impact on Material Resources	3	3	2	2	1	3
Siting Flexibility	1	1	3	2	2	3
Operating Availability	3	1	3	3	1	2
Construction Lead Time	1	1	3	2	2	2
Safety	3	2	2	2	2	2
Power System Compatibility	2	2	3	3	2	2
Impact on Fuel Resources	2	1	3	2	3	3

ORIGINAL PAGE IS  
OF POOR QUALITY

Compressed air storage would use a modified gas turbine, a separate compressor, and a generator. The compressor would be driven by the generator operating as a motor during off-peak periods to store air in a suitable space underground. During periods of peak load on the electric system, the stored compressed air would be burned with fuel in the gas turbine to drive the generator. The required R and D relates mainly to adopting and modifying existing equipment for air storage. This is likely to be accomplished by industry as commercial opportunities arise. Geological survey work for suitable sites and investigation of energy losses in storing and moving air are also needed.

Storage batteries appear to be one of the likeliest energy storage technologies to reach fruition. But so far no battery exists whose performance and costs are adequate to compete with pumped hydro storage. EPRI's battery program is directed toward potentially cost-competitive advanced batteries based on the sodium-sulphur, lithium-iron sulfide, and zinc chlorine electrochemical systems. The possibility of engineering lead-acid batteries into near term utility energy storage systems is also under assessment, by EPRI.

In general, there are three possible duty cycles that can be used for the operation of rechargeable storage batteries [El-Badry-74]:

The daily cycle -- the storage system is charged at night and during the early morning hours and discharged during the peak load period. This cycle requires the minimum energy storage capacity; however, it does not utilize all the available off-peak energy.

The weekly cycle -- the storage system is charged on the weekend and also during the off-peak periods of the weekdays and discharged during the peak load periods of the weekdays. The weekly cycle requires more than twice the energy storage capacity needed for the daily cycle, but it would utilize most of the available off-peak energy.

The seasonal cycle -- the storage system is charged during weekends and weekdays all year and only discharged when system peak loads occur. This is usually during the summer (but possibly the winter) season. This cycle is capable of utilizing all the available off-peak energy, although it requires a prohibitive amount of storage capacity.

In considering the installation of rechargeable storage battery capacity, energy capacity (KWH) as well as power capacity (KW) must be considered. For example, any given amount of available off-peak energy could be utilized with a number of different KWH/KW capacity combinations. The optimum amount of installed battery capacity on any electric power system is a function of the load shape, the amount, distribution, and cost of available off-peak energy, and the desired mode of operation or duty cycle. Table J.2.3.1-3 illustrates a summary of rechargeable storage battery installed capacity:

The cost of battery capacity is an important element in this study and is usually represented in terms of dollars per kilowatt hour of storage capacity. Capital costs of present day battery systems are in the order of approximately \$50/KWH. Projected capital costs of advanced design battery systems currently under development have been projected to be in the order of \$20/KWH. It is interesting to compare the cost in \$/KW for a battery storage system with the installed capital costs for gas turbines and pumped hydro storage. The installed capital costs for gas turbines and pumped storage hydro range from \$100 to \$150/KW and \$200 to \$300/KW respectively. The estimated base installed cost for an advanced technology lead-acid battery system is \$300/KW. [Brown-74] This figure is based on a ten hour battery system.

Studies show that the larger storage capacity requirements of the weekly cycle could economically limit the application of storage batteries in electric power systems to the daily cycle operation.

Among the primary advantages of battery storage systems are:

- Short lead time
- Improved utility load factor
- Remote operation
- Inner city siting
- Low maintenance cost
- Rapid dispatch
- Transmission savings

The disadvantages are:

- Relatively high capital cost at present
- Short life
- Limited storage capacity
- Inverter cost and electromagnetic interference

TABLE J.2.3.1-3  
RECHARGEABLE STORAGE BATTERY CAPACITY

<u>Duty Cycle</u>	<u>Battery Conversion Efficiency in Percent</u>	<u>Installed Battery Power Capacity in Percent of Total System Installed Capacity</u>
Daily	75	9
	100	12
Weekly	75	15
	100	20



## Advanced Transmission Systems

Cryogenic systems operate at temperatures much below ambient in order to take advantage of the fact that the electrical resistance of a metal diminishes as its temperature is lowered. Although the ohmic losses in the conductor are reduced, this benefit is partially offset by the refrigeration that is required to remove the heat leaking in from the outside and the residual losses which appear as heat dissipated at the low temperature. Since refrigeration requires a significant amount of power, care is required to insure that there is a net reduction in the losses of the system. Economic analysis shows, however, that energy losses are not significant contributors to operating costs. Rather it is important that cryogenic systems have lower installed capital costs since these dominate the overall costs.

Cryogenic systems are of two types: cryoresistive and superconducting. In the former, the resistance of the metal remains finite although it is considerably reduced below its value at room temperature; in the latter the DC resistance of the material becomes identically zero when the metal becomes superconducting, although certain losses remain when the metal is exposed to alternating currents and electromagnetic fields.

Two types of cryoresistive cable systems have been proposed, both of which operate at approximately 80°K and are cooled by liquid nitrogen. In one, stranded flexible aluminum conductors are insulated in a manner similar to a classical oil-paper cable. The three phases are contained within a cryogenic enclosure through which flows liquid nitrogen as the coolant and impregnant. This type of system is proposed for high power operation at approximately 3500 MW. The second cryoresistive system consists of three hollow rigid phase conductors mounted within a single vacuum envelope. The vacuum provides both thermal and electrical insulation between the phase conductors and between the conductors and the enclosure. The coolant flows inside the conductors. It is claimed that this design permits simple fabrication and inexpensive assembly. It is designed for a capacity of 1000 MW at 230 kV, but can be expanded to 2000 MW by the addition of three refrigerators to the original single unit. Both types of cryoresistive systems have gone through experimental stages and are approaching demonstration project status. [FPC-73]

Two superconducting AC systems are now under development in the U. S. In one design, three coaxial phase systems, in which the niobium superconductor is plated upon copper tubes, are arranged in trefoil. The liquid helium, acting as coolant and dielectric, flows between each phase conductor and its shield. The whole is contained within the double-walled vacuum cryogenic enclosure. The system is rigid and its field installation involves approximately 8 vacuum-tight or superconducting connections at 50 foot intervals. The second superconducting system more closely resembles a cryogenic version of the pipe-type cable. The cryogenic enclosure is assembled in

sections and into it is pulled a flexible superconducting cable in which the three phases are insulated from one another by plastic tape. Both systems operate at approximately 5°K. At this temperature, the power requirements and the capital costs of the refrigeration systems are high. For example, approximately 400 watts input power are required for each thermal watt that must be extracted at 4°K. The refrigerator adds substantially to the cost and hence it is essential that the AC losses and the heat leak into the cryogenic conductors be reduced to the minimum in superconducting systems. [ERC-72] Table J.2.3.2-4 shows the Alabama Power Company Income Statement (1973).

Because the current ratings of proposed cryogenic resistive and superconducting AC cables are substantially greater (3 to 5 times or more) than those of conventional underground cables or overhead lines, presently available circuit breakers are inadequate by a wide margin for protection of the superconducting or cryogenic cables. Thus, major advances in circuit breaker technology are essential if integration of proposed superconducting or cryogenic cables into existing power systems is to be considered. Furthermore, the research and development on circuit breaker technology must proceed apace with the work on cables. Otherwise, successful development of lines will not lead to their system use. Similar problems may exist with other terminal equipment such as potheads, surge suppressers, disconnect switches, etc. It is essential to make comprehensive studies of proposed new transmission technologies to identify the problems of auxiliaries and the costs of integrating new transmission technologies into existing power networks.

### J.2.3.2 THE ECONOMICS

Considerable discussion of utilities' economic health is going on. Chapter 1 and Appendix N as well as this appendix and Chapter 10 contain information on the economic problems confronting utilities.

## J.3 ACTIONS IN OTHER SECTORS

### J.3.1 INDUSTRY

Increased efficiency is a benefit of electrification.

### J.3.2 TRANSPORTATION

In order to utilize appreciable electricity, the transportation sector would have to be completely redesigned. The potential for efficiency improvements is very large by electrification of transportation.

TABLE J .2.3.2-4. ALABAMA POWER COMPANY INCOME STATEMENT, 1973 CAPCSR-741

OPERATING REVENUES - ELECTRIC	<u>396,841</u>
OPERATING EXPENSES - ELECTRIC:	
Operation	
Fuel	84,573
Purchased and interchanged power, net	17,140
Other	57,240
Maintenance	26,419
Depreciation and amortization	40,605
Taxes other than income taxes	30,241
Income taxes	
Federal	23,869
State	779
Deferred	19,252
Deferred in prior years, credit	2,171
Investment tax credit	<u>2,347</u>
Total income taxes	<u>44,076</u>
Total operating expenses	<u>300,294</u>
OPERATING INCOME - ELECTRIC	<u>96,547</u>
OTHER INCOME AND DEDUCTIONS:	
Allowance for funds used during construction	23,871
Dividends from SEGCO	1,919
Other, net	7,990
INCOME BEFORE INTEREST CHARGES	<u>130,327</u>
INTEREST CHARGES:	
Interest on first mortgage bonds	50,441
Other interest expense	<u>5,031</u>
Total interest charges	<u>55,472</u>
INCOME BEFORE EXTRAORDINARY ITEM	<u>74,855</u>
EXTRAORDINARY ITEM:	
Dividends from SEGCO paid from earnings accumulated prior to January 1, 1963	<u>-</u>
NET INCOME	<u>74,855</u>
DIVIDENDS ON PREFERRED STOCK	<u>9,766</u>
NET INCOME AFTER DIVIDENDS ON PREFERRED STOCK	<u><u>65,089</u></u>

ORIGINAL PAGE IS  
OF POOR QUALITY

### J.3.2.1 FIXED RAIL

Some of the high speed passenger railway lines in the United States are now driven electrically. However, less than one per cent of the 220,000 track miles have been electrified. This is compared with electrified railway systems in some other nations, such as 13,000 route miles in Russia, 6,000 miles in Japan, 6,000 in Italy, 5,000 in France and 4,700 in Sweden. The reasons for this lack of U. S. railway electrification are noted as:

Competition from other modes and insufficient traffic to warrant electrification.

Insufficient interest from electric power suppliers and the railroad managements.

Lagging electrification technology compared with advanced diesel-electric locomotives.

High capital electrification cost.

An abundance of cheap diesel fuel (until the current energy shortage).

In an electric economy where the primary energy is supplied by nuclear fuels and/or coal, railway electrification becomes a vital issue. It appears that those routes enjoying a sufficiently high freight density to warrant the high capital cost should be electrified. The remainder could be powered by hydrogen, a fuel product of the electric economy.

Some obstacles to railroad electrification seem to be:

The inflexibility of the electric locomotive (it can only operate under an electric wire).

Reluctance of railroads to depend on other companies (e.g., an electric utility) for its source of power, particularly when the utilities have not appeared interested.

Uncertainty regarding future cost of electric power vs. other alternative fuels.

Present large investment in diesel-powered locomotives and the problem of economically phasing them out.

The need for cooperative contracts with the various utilities in the area common to the railway system

The tremendous capital outlay to finance the original installation is on the order of \$100 million per 1000 track miles. This is by far the greatest hurdle to electrification. The railroads simply cannot finance this capital cost! Their rate of capital formation is insufficient. Someone else must assist. One possibility, of course, would be for the electric utility industry to finance the installation of the catenary distribution system for supplying power to the locomotives similar to the way they provide distribution systems to their other customers. The railroads would still have to make the necessary investment in signal systems, communications, clearances and replacement locomotives. If the railroads only make this portion of the investment, it appears that they can then earn a reasonable return on their portion of the investment whenever the following conditions prevail:

Maximum operating speeds exceed 70 mph

The electrified route extends for at least 500 miles of double track or 1,000 miles of single track

There is a minimum freight density of 35 million tons per track per year

Where a significant portion of the traffic is in the high performance category

Where the power cost does not exceed the cost of diesel fuel

These requirements apparently are met on about 10% of the trackage or roughly 22,000 route miles. For this selected portion of the U. S. railroads, electrification seems to offer many advantages such as:

An annual saving of three billion gallons of diesel fuel

The number of wearing parts per electric locomotive are thousands less than in a comparable diesel

The electric locomotive can be made with much more horsepower

A roughly 15% lower first cost per locomotive.

Maintenance costs are reduced by two-thirds. .

Economic life is doubled.

Down time for maintenance is reduced to one half.

Lower inventories are required:

10 to 20 days' supply of diesel fuel and lube oil no longer needed

Around \$1,000 of spare parts per engine not needed.

6,000 to 8,000 gallons of diesel fuel consumed per engine annually while idling, would be saved.

Electric locomotives can be built in 9,000 to 10,000 hp sizes and larger if necessary) whereas 6,600 hp seems to be about the maximum practical size for a diesel. These larger sizes mean fewer locomotives for a given load and speed and hence a lower investment.

Savings in operating costs allow initial investment to be recovered in less than 5 years.

Energy supply from nuclear fuel and/or coal would be assured.

The cost of this 22,000-track miles of electrification will be nearly \$2 billion. This appears large until we look at the \$50 billion plowed into the interstate highway system -- a cross country network of modern highway which loses much of its advantage with a national speed limit of 55 mph! We already spend a billion dollars each year for air traffic control and may soon require twice this amount for annual highway repair.

It has already been implied that this funding might possibly come via the electric utilities themselves. It could also possibly come from interested third parties who see the apparent opportunity for payback in less than six years -- a rather choice investment, and particularly so if the federal government would provide a tax incentive. Another possibility is federal subsidy.

Total installation time for a 1,000 mile module is estimated at about 3 years, and the annual energy requirement is estimated at roughly one billion kWh.

The references used in the discussion of fixed rail were sequentially [Lancaster-75], [Silien-75], [Morris-75], [Heck-75], [Vanderslice-74], [Fisher-74] and [Wyman-69].

### J.3.2.2 BATTERIES

In an electric economy, the battery powered automobile and delivery truck play an important role. The electric powered vehicle is not really new. Back in the 1910-1920 era, several companies operated fleets of electric vehicles.

There now exists over 108 electric delivery vehicles in the United States and Canada. Their performance records are proving their cost effectiveness over gasoline-powered fleet delivery vehicles. The required cost of the necessary pollution control devices, the increased fuel cost and much higher service and maintenance costs of multi-stop gasoline-fueled vehicles should cause fleet operators to seriously examine the attributes of currently available electric vehicles. In fact, the AM General Corporation is delivering 350 electric-powered jeeps to the postal service this year.

Electric automobiles which are currently available in the U. S. are listed in Table J.3.2.2-1.

Other newcomers in the electric vehicle arena are the Otis electric delivery van, the Battronic minivan and the Battronic truck. Some writers are predicting that there will be somewhere around 5 million electric cars in service by 1985.

There is no reason why all passenger and delivery vehicles operated in urban and suburban areas could not be electric if only enough electrical energy could be made available for charging the batteries. The electric automobiles are more efficient than the gasoline-powered vehicles that they replace. This is shown in Figure J.3.2.2-1. [Ankrum-74]

Performance tests in which a conventional post office delivery van and an electric van traveled the same route at the same time yielded an energy cost of six cents per mile for gasoline vs. one cent per mile for the electric van.

The electric vehicle can be recharged at night when utilities are lightly loaded and hence obtain off-peak rates. The electric utilities will be glad to even up their loads to a greater extent as well as utilize more of their capacity at night. The electric vehicle will not pollute the air. It does not idle at stops and, hence, has an inherent advantage for urban delivery service. It makes no noise except for a small whine during acceleration. This is important since noise pollution is a major health and safety issue.

TABLE J.3.2.2-1. AVAILABLE ELECTRIC AUTOS

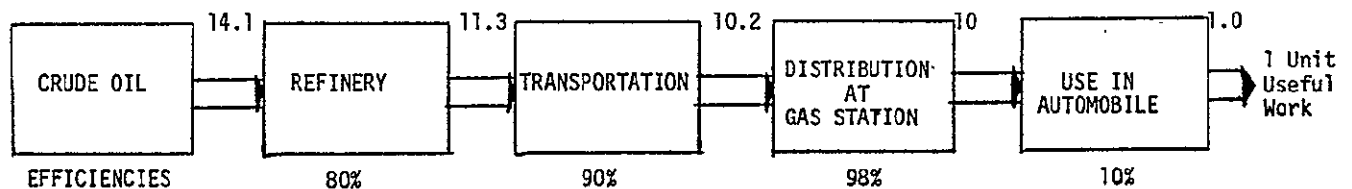
	Citi Car	Elcar	Islander
Weight	1250 lbs.	1091 lbs.	2200 lbs.
Passengers	2	2	4
Price	\$2690 <u>or</u>	\$2995 <u>or</u> * 3395 <u>or</u> **	\$5000.00
Range	50 miles	50 miles	
Speed	30 mph <sup>†</sup>	30 mph <sup>†</sup>	

\*1,000 series

\*\*2,000 series

<sup>†</sup>approximate

## INPUT ENERGY UNITS REQUIRED



## INPUT ENERGY UNITS REQUIRED

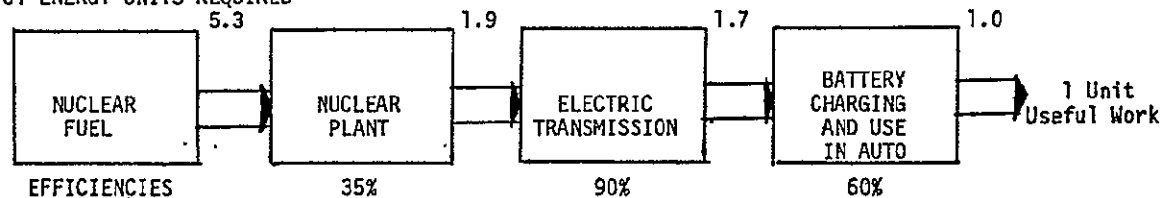


FIGURE J.3.2.2-1. COMPARISON OF THE ELECTRIC AND GASOLINE-POWERED CARS [ANKRUM-74]



Storage batteries are required for all electric vehicles. Some of those receiving current attention are lead-acid, lithium chloride-potassium chloride, nickel-zinc, sodium-sulfur, nickel-cadmium, and lithium-sulfur.

This last-named battery looks very interesting. The battery cells were developed at the Argonne National Laboratory. The lithium-sulfide test cells have produced as much as five times the energy produced by a comparable lead-acid battery. Argonne engineers expect that ultimately such cells will have lifetimes of 5 to 8 years and be capable of sustaining between 1000 and 1500 charge and discharge cycles. A recent design study [Walters-75] has shown that a 150-V battery with a storage capability of 42 kWh can be used to power a 1975 Ford Mustang II. The battery is 36" long, 21" wide and 22" high. It weights 800 pounds. In stop-and-start city driving, the range of the car will be approximately 120 miles. The vehicle can accelerate to 50 mph in 15 seconds and to 60 mph in 23 seconds. The maximum speed will be about 80 mph. The projected cost will be from \$800 to \$1250, whereas an equivalent lead-acid battery will cost around \$2500.

The battery of an electric vehicle must be charged daily and this is a slow process. It is visualized that parking lots in cities and at railway stations and airports might be equipped with electrical outlets where motorists could recharge while parking. In this way the parking fee would be partly for the recharge.

Since the battery powered vehicle is limited in its range of travel, it seems ideal for urban and suburban travel but not for extended highway trips. It should, however, team up well with the auto train whereby the driver could relax, read, write, etc. during the trip instead of having to endure the hardship of driving. He would still have his vehicle with him, however, for local transportation at his destination. As an alternate, airports and railroads might well consider the operation of auto rentals for their customers. There might be less risk on the part of these fleet operators in the case of electric vehicles than for gasoline-powered vehicles.

#### J.3.2.3 ALTERNATE FUELS

In an electric economy, alternate fuels play a vital role. Liquid hydrogen exhibits a great potential as an aviation fuel because:

It possesses a high energy content

It has a large cooling capacity

It produces a minimal environmental impact

Its supply is essentially unlimited

It will greatly improve the performance of subsonic and supersonic aircraft, while for hypersonic transports it will be a must. Liquid hydrogen is no more hazardous than methane or gasoline [Small-74], and furthermore, it possesses several safety advantages. The performance of hydrogen engines more than compensates for the increased size and added weight of the required cryogenic fuel tanks. Use of hydrogen permits a change in fuel tankage arrangement which yields a drastic reduction in take-off weight of subsonic aircraft as shown in Figure J.3.2.3-1. Air pollution is vastly reduced by burning hydrogen. The noise level is reduced by using hydrogen as shown in Figure J.3.2.3-2.

Hydrogen fuel is expected to become cheaper as its use increases. It looks like the aircraft fuel of the future in an electrified economy.

Hydrogen could become a good replacement fuel for automotive gasoline and railroad diesel fuel in the electric economy. It could be produced either by electrolysis or water splitting and hence be practically unlimited in supply provided adequate nuclear power were available. It would produce very small air pollution and practically none if burned with oxygen. Hydrogen is not extremely hazardous, and in fact, federal regulations already exist for its transportation and storage. They are shown in Table J.3.2.3-1. A vehicle with a 20-gal. liquid tank would require a 50-gal. liquid hydrogen Dewar. Metallic hydrides also look promising as automotive fuels and in some respects seem better than liquid hydrogen. Comparisons of these fuels are illustrated in Table J.3.2.3-2. Storage and distribution systems for hydrogen would be somewhat larger than for gasoline as shown in Table J.3.2.3-3. Comparative requirements for the nation are shown in Tables J.3.2.3-4 and J.3.2.3-5.

In general, an orderly conversion from gasoline to hydrogen fuel would require an enormous national commitment. It could be done, however, and the public probably would hasten to this end rather than forego driving. An educational program would be required for training production-plant and service-station personnel as well as for indoctrination of the

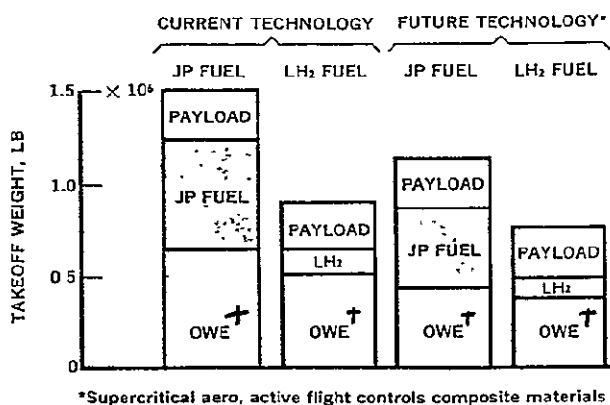


FIGURE J.3.2.3-1. PROJECTED ADVANCED CARGO TRANSPORTS,  
 $M_{cruise} = 0.85$ , RANGE = 5070 NAUTICAL MILES,  
 PAYLOAD = 250,000 LB. [SMALL-74]

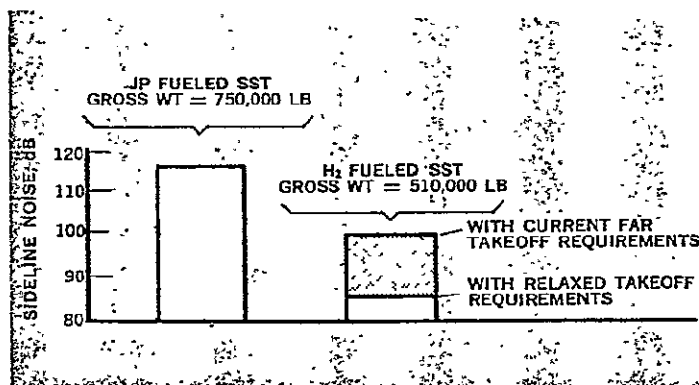


FIGURE J.3.2.3-2. SIDELINE NOISE AT BRAKE RELEASE,  
 M-3 SST. [SMALL-74]

TABLE J.3.2.3-1. [STEWART-74]

## Regulatory Guidelines for Distribution of Hydrogen

Distribution Method	Equipment Specifications	Shipping Regulations	Installation Standards
Liquid Cylinders	Title 49 CFR 178.57	Title 49 CFR 173.316	NFPA 50B
Liquid Trailer	ASME/(Ref. CGA 341)	Special Permit	-
Liquid Tank Car	Title 49 CFR 179.400	Title 49 CFR 173.316	-
Liquid Customer Station	ASME	-	NFPA 50B
Gas Cylinders	ASME/Title 49 CFR 178.36-.37	Title 49 CFR 173.302	NFPA 50A
Gas-Cylinder Trailer	ASME/Title 49 CFR 178.36-.37	Title 49 CFR 173.302	NFPA 50A
Gas Pipeline	ANSI B31.8	-	Title 49 CFR Part 192

TABLE J.3.2.3-2. COMPARISON OF FUEL STORAGE SYSTEMS FOR A VEHICLE RANGE OF 260 MI (418 KM) [STEWART-74]

	Gasoline	Cryogenic LH <sub>2</sub>	Compressed GH <sub>2</sub>	Metallic Hydride
Fuel:				
weight, lb (kg)	118 (53.5)	29.5 (13.4)	29.5 (13.4)	400 (181) (MgH <sub>2</sub> )
volume, ft <sup>3</sup> (m <sup>3</sup> )	2.6 (0.07) (20 gal)	6.7 (0.19) (50 gal)	35 (1.0)	8 (0.23)
Tankage:				
weight, lb (kg)	30 (13.6)	400 (181)	3000(1361)	100 (45.4)
volume, ft <sup>3</sup> (m <sup>3</sup> )	3 (0.08)	10 (0.28)	54 (1.53)	9 (0.25)
Total:				
weight, lb (kg)	148 (67)	430 (195)	3030(1374)	500 (227)

TABLE J.3.2.3-3. COMPARISON OF  
GASOLINE AND LIQUID-HYDROGEN SYSTEMS [STEWART-74]

	Gasoline	LH <sub>2</sub>
Total usage, billions of gal/yr (10 <sup>9</sup> l/yr)	100 (379)	250 (946)
Station storage, thousands of gal (10 <sup>3</sup> l)	15 (57)	38 (144)
Distribution per station millions of gal/yr (10 <sup>6</sup> l/yr)	0.36 (1.4)	0.90 (3.4)
Delivery vehicle capacity, gal (l)	8650 (32,740)	13,000 (49,205)
Average number of deliveries/yr	41	72 or 42*
Car tank size, gal (l)	20 (76)	50 (189)

\*If 22,000 gal (83,270 l) deliveries were made

TABLE J.3.2.3-4. SUMMARY OF  
LIQUID-HYDROGEN REQUIREMENTS [STEWART-74]

Item	Liquid Hydrogen, Billions of gal per yr (10 <sup>9</sup> l/yr)
Consumed in automobile engines	250 (946)
Losses:	
Producer to transport	1.094 <sup>a</sup> (4.141)
Transport boiloff	0.234 <sup>b</sup> (0.889)
Transport to service station	2.105 <sup>a</sup> (7.967)
Station boiloff	8.322 (31.499)
Station to automobile	11.695 (44.266)
Automobile Dewar Boiloff	18.25 <sup>b</sup> (69.076)
Automobile Dewar chilldown	0.31 (1.173)
Total losses	42 (159)
Total production required	292 (1105)

<sup>a</sup>Includes line chilldown, line boiloff, left in line, and flashing losses.

<sup>b</sup>Avoidable losses.

TABLE J.3.2.3-5. LIQUID-HYDROGEN PRODUCTION  
AND DISTRIBUTION SYSTEM COSTS [STEWART-74]

	Billions of Dollars
GH <sub>2</sub> Electrolysis facilities	23
135 plants of \$170 million each	
73 ton/hr (66,226 kg/hr) capacity each	
Liquefaction facilities	48
800 plants at \$60 million each	
300 ton/day (272,160 kg/day)	
capacity each	
Service stations	60
300,000 stations at \$200,000 each	
(includes \$100,000 for LH <sub>2</sub> tanks)	
LH <sub>2</sub> transport trailers	2
20,000 trailers at \$100,000 each	
13,000 gal (49,205 l) capacity for each	
Total cost	133

general public.

A selected list of alternate fuels could be chosen as:

Synthetic gasoline or other liquid hydrocarbons similar to today's transportation fuels

Methane

Methanol

Ethanol

Hydrogen

Ammonia

Hydrazine

This list is by no means complete. For example, the metallic hydrides may, after more research and development, prove to be very excellent fuels indeed. The fuels which are more nearly ready for extended use are methane, methanol, ethanol, and ammonia. Each has certain advantages and disadvantages. Each can be produced in vast quantities from resources which are plentiful, but a source of energy is needed. This apparent energy source is nuclear, and since nuclear-thermal techniques require more research, electricity must be generated from nuclear produced heat. Hence, methanol can be synthesized in vast quantities from water-derived hydrogen and coal-derived carbon dioxide.

An available technology exists today for utilizing solar energy to grow suitable crops and then convert them into ethanol by fermentation. In this fashion, large scale solar-energy farms could be utilized to produce vast quantities of ethanol, but the economics have not yet been assessed.

Methanol is a cleaner burning fuel than gasoline, and this makes it more ecologically acceptable. Emissions are compared in Table J.3.2.3-6 (note that MBT in this table refers to "Minimum spark timing for Best Torque"). Furthermore, it can be made from coal in vast quantities by supplying adequate energy (electrical energy in this discussion).

One drawback of methanol as a transportation fuel is its low heat of combustion per unit volume. Since its energy content is only half that of gasoline, a fuel tank at least twice as large would be required. The fuel economy of methanol compares favorably with that of gasoline however as shown in Table J.3.2.3-7.

TABLE J.3.2.3-6. EMISSIONS AT 50 MPH  
 CRUISE FOR METHANOL AND GASOLINE FUELS  
 (350-CID ENGINE OPERATED AT MBT SPARK TIMING FOR BOTH FUELS [FLEMING-75])

Fuel	Air-fuel Equivalence Ratio	Emissions, Grams/Mile		
		CO	HC	NO <sub>x</sub>
Methanol	0.99	22.5	1.29 (as CH <sub>3</sub> OH)	3.69
Gasoline	0.99	23.5	1.67 (as CH <sub>1.85</sub> )	7.95

TABLE J.3.2.3-7. FUEL ECONOMY AT 50 MPH  
 CRUISE FOR METHANOL AND GASOLINE FUELS  
 (350-CID ENGINE OPERATED AT MBT SPARK TIMING FOR BOTH FUELS) [FLEMING-75]

Fuel	Air-fuel Equivalence Ratio	Fuel Economy	
		Miles per Gallon	Miles per Energy Unit
Methanol	0.99	8.83	18.08
Gasoline	0.99	17.20	17.20



A methanol fueled engine is difficult to crank at low temperature. Furthermore, deterioration of some types of metal plating, certain plastics and a few die cast carburetor parts have been reported with methanol. However, it is believed that these problems can be overcome.

In spite of these problem areas, methanol looks promising as a transportation fuel. Given enough electrical energy, it could be produced in enormous quantities from readily available resources. It is easy to handle, easy to store, is not hazardous, has low emission potential, and a high thermal energy efficiency. It may well become the transportation fuel of the future.

Fuels that can be synthesized from air and/or water, include hydrogen, hydrogen peroxide, hydrazine, and ammonia. Of these, ammonia looks the most promising for the near future. Ammonia (or any non-carbon fuel) will not contribute to carbon monoxide, carbon dioxide, or unburned hydrocarbons in vehicle exhausts. Furthermore, the nitric oxide will be less than one fifth of that in the case of gasoline fueled engines. Ammonia has an extremely high octane rating and achieves it without the use of lead or any other additives. The heating value of ammonia is low compared with gasoline, and, therefore, an ammonia tank for a vehicle would need to be about three times as large as a comparable one for gasoline. Ammonia is toxic and caution must be exercised in handling it. However, it has a characteristic odor. Furthermore, it is lighter than air, so it will have a tendency to rise in the atmosphere and disperse. It does not constitute any appreciable fire hazard. It is readily vaporized which is very essential for spark ignition engines. It is noted that copper, brass, and zinc are attacked by ammonia and hence, any affected parts normally constructed with these materials should be made of steel or aluminum. On the whole, ammonia looks like another viable candidate for transportation fuel in an electric economy. The various candidate fuels are compared quantitatively in Table F.5-1.

### J.3.3 ELECTRIFICATION OF RESIDENTIAL HEATING, VENTILATION AND AIR CONDITIONING (HVAC) SYSTEMS

Electrical systems are generally cleaner. Those incorporating a heat pump can have greater fuel to end-use efficiency than any other type system. [APC-75] Heat pumps are reversible air conditioners, and many new houses have central air conditioning. Thus, supplying heat pumps for the HVAC systems in new houses should have little effect on the present economy. Regarding existing houses, installation of heat pumps could replace both central air conditioning and worn out furnaces. Lastly, heat pumps, as air conditioners in the past, could be added to

present oil or gas furnace, hot air systems. Installation of three million additional heat pumps, projected through 1980 and being prepared for by training personnel [GE-1974], should have only a mild stimulating effect on the economy. Considering a weighted national average (cf. Appendix G.5) of 147.6 million BTUs/yr per family unit, the average national savings in fuel oil, over the next five years, is 0.2 of a quad each year. The former value was derived by considering the overall electrical system efficiency (fuel BTUs to end use BTUs) of 33% or multiplying the end use BTUs of 49.2 million (from Appendix G.5) by 3.

As implied above, the change to the heat pump systems would not be limited by availability of materials or manpower for installation (same as for central air conditioning). The only obstacle is public acceptance and education; it is felt that a high acceptance could be achieved by an intensive information program. The improvement in the nation's status, noted above, warrants such a program.

In 1972, residential hot water systems required 1.7 quads, 65% being from oil or natural gas [APC-75]. Changing these heaters to an electrical type could save that many quads or 800 thousand bbl per day in oil (or equivalents).

For each BTU delivered to an end-use consumer, three are required in fuel. With electrical hot water heaters having an efficiency of 75%, four BTUs in fuel are required for each one delivered to the water. For gas heaters (50% efficiency), two BTU's of fuel are required for each BTU to the water. Improved insulation, while improving both types, can make electrical hot water heaters economically advantageous at 1975 prices for electricity and natural gas. The advantage will increase with the anticipated, rising price of natural gas.

The projected housing inventory for 1985 is 89 million [PI-74]. Of these, 39% or 32 million are expected to be electric. This would effect an increase of 14 million over the electric heaters in use in 1972 [Wh-75]. The increase of electric hot water heaters from 16 million in 1970 [PI-74] to 18 million in 1972 [Wh-75], or approximately one million per year, indicates that the 1.4 million average required for the 14 million increase over the ten years (1975 to 85) would require a 40% increase in production. While this alone should have only a small effect on the economy, with other equipment required for electrification, planning will be necessary to reduce the total effect on the U. S. economy.

The main materials' requirements for the electrical equipment needed in electrification are copper and steel. It seems probable that planning and cooperation will be required to divert these materials from other users.

There exists a problem created by rapidly growing air conditioning loads for summer peaking utilities. Increased saturation of air conditioning results in deteriorating load factors. The following measures are recommended to reduce the adverse impact of increased saturation of air conditioning:

More efficient air conditioning units.

Better building designs, in particular better insulation.

Storage of "cold" in the form of cold water, ice, or salt hydrates.

Change of the pattern of use of other household loads to avoid coincidence with system peak. This would require time of day metering and a rate incentive to avoid peak periods.

Reduction of seasonal differences in load through encouragement of electric heating in winter (heat pumps in particular).

It is felt that residential customers will be encouraged to change their normal pattern of use of appliances if given sufficient economic incentive.

Increased saturation caused by electric heating resulted in deteriorated annual load factors during winter peaks. In 1974, about 50 percent of new single family construction in the U. S. was electrically heated. In 1974, electric furnaces represented about 50 percent of total electric heating installations, heat pumps represented a little under 10 percent, and the rest was resistance heating (baseboard and ceiling cable). Resistance heating with individual room thermostatic control has better diversity than central furnace or heat pump unit. The high proportion of electric heating in new construction and the increase in conversions are due to shortages of natural gas and concern over oil.

Two areas that may help in load management are storage of heat and some mixed heating. An electric heating system may be supplemented by an oil or lignite-fired system to top up the electric system during periods of peak heating demand. The future for mixed heating systems where the relative proportions of storage and direct heating are set to minimize capital plus operating costs is promising.

It is interesting to know that the utilities in England, Belgium, and West Germany promote predominantly storage heating. The idea is to have all of the storage heating on a separate circuit (used mainly in Belgium and West Germany and partially in England) whose activation is controlled by the utility through remote ripple control. The cost of a ripple control receiver is about \$85. Many U. S. utilities are considering a ripple control system that could be used for meter reading in addition to control of loads or meter switching.

Another point that is worth mentioning here is the future of the heat pump. It would be uneconomical to design the heat pump to supply peak heating demand on the coldest days of the year. It should be supplemented by a source of topping heat during peak hours.

A-1

## APPENDIX K. DIVERSIFICATION

### K.1 DIVERSIFICATION ACTIONS

Briefly digested below are the major characteristics of each of the systems which contribute to diversification. Energy potential estimates are given for each. In some cases those estimates reflect prognostications made by ERDA [ERDA-48], while those which do not are based on a variety of other projections.

#### K.1.1 COAL, EXTRACTION

Type Systems: Contour mining, area mining, auger mining, room and pillar mining and longwall mining

Primary Locations: Principle area of present mining is located around the Appalachian mountains, north into Pennsylvania and west into Kentucky and Illinois. Future development is expected to grow rapidly in Northern Great Plains.

Potential: 1985, 22 quads; 2000, 30-40 quads.

Primary Requirements: Strip mine shovels and blasthole drills (problems include availability of steel castings, steelplate, forgings, bearings, electric motors and neoprene). Continuous miners, methane detectors, respirators and other safety equipment. Hopper cars and barges.

Means of Implementation: Expansion of the industry is occurring rapidly in the Northern Great Plains but is impaired by concern over environmental impacts. A clear and precise set of strip mining and deep mining regulations must be outlined and strictly enforced. Environmental safeguards must be outlined in a long term overall plan. Injunctions should not be given against construction except in those cases where the approved restrictions are violated.

Impacts: Vegetation will be destroyed and underground water sources may be upset. In eastern regions problems are encountered with subsidence and mine drainage. In western areas, alkaline materials may be leached from mines. Temporary surface disruption will reduce cover and food supply of surrounding wildlife.

### K.1.2 COAL UTILIZATION

Type Systems: electric power plants, steel manufacture and cement plants. Refer to Appendix D for further description of plants. See Appendix I for plant conversions.

Primary Location: Widely dispersed across United States although greatest use is in eastern part of the country.

Potential: 1985, 22 quads; 2000, 30 - 40 quads.

Primary Requirements: Development of effective, reliable and low cost air pollution equipment. Capital to develop mines and the more expensive coal furnaces.

Means of Implementation: Readjustment of environmental standards to optimize on both air quality and energy needs.

Impacts: Conversion of plants burning alternate fuels with coal facilities will require either relaxation of environmental standards or high capital expenditures and the concomitant rate increases. Conversion of plants without coal facilities to utilize coal will generally require rebuilding of the boiler. This is both expensive and time consuming. A retrofit program could seriously affect reserves and might lead to wide spread blackouts.

### K.1.3 COAL, CONVERSION

Type Systems: liquifaction, gasification, and solvent refined coal. See Appendix D for further discussion.

Primary locations: Northern Great Plains.

Potential: 1985,  $1.3 \times 10^9$  ft<sup>3</sup>/year gas, 5000 bbl/day liquid; 2000,  $6.2 \times 10^9$  ft<sup>3</sup>/year gas,  $3.5 \times 10^6$  bbl/day liquid. [PI-74-3,107]

Means of Implementation: Support of research in advanced coal conversion techniques. Improved legal procedures to allow needed trade off: environmental and energy needs. Readjust pricing regulations to allow mixture of SNG and natural gas to be sold at a mixed price. Guarantee of investment.

Impacts: Large demands will be placed on water in arid regions. Pipelines may be utilized but would disrupt agricultural areas.

#### K.1.4 OIL (DOMESTIC)

Type system: conventional well, enhanced recovery

Primary Location: Outer continental shelf, arctic, deep and shallow inner continental in several states predominantly in the south central region. Enhanced recovery at existing sites.

Potential: 1985, 12 quads; 2000, 9 quads.

Primary Requirements: Capital, drilling rigs, platforms, pipe, exploration crews, rig men, refineries, water, steel, cement, processing plants.

Means of Implementation: Pricing policy, improved leasing procedures, technological development of shale oil recovery methods and very deep O.C.S. drilling.

Impacts: Water and land use, manufacturing facilities, ecological balances, lifestyles, trained personnel, social acceptance.

#### K.1.5 NATURAL GAS

Type Systems: Conventional well, stimulation of tight formations.

Primary Location: Deep and shallow inner continental of certain states, arctic, outer continental shelf.

Potential: 1985, 10 quads; 2000, 7 quads.

Primary Requirements: Capital, drilling rigs, platforms, pipe, exploration crews, rigmen, water, steel, concrete.

Means of Implementation: Realistic pricing policy, improved leasing procedures, technological development of stimulation techniques.

Impacts: Water and land use, manufacturing facilities, ecological balance, trained personnel, land use policy, social acceptance.

#### K.1.6 OIL SHALE

Primary Location: Colorado, Wyoming, Utah

Type Systems: above ground retorting with surface mining or deep mining, in situ.

Potential: 1985, 2.5 quads; 2000, 4.5 quads [ERDA-48].

Primary Requirements: large labor force, improved water recovery systems, environmentally satisfactory disposal and land reclamation programs, possible oil-price guarantees, adequate supplies of water (above ground retorting), adequate manpower.

Means of Implementation: Develop leasing rules more conducive to large-scale shale mining.

Impacts: Destruction of terrain, disposal problems, particulate emissions, leaching and consequential productivity reduction of land, possible subsidence, extreme pressure on water resources (less for in situ).

#### K.1.7 HYDROELECTRICITY

Type System: hydroelectricity

Primary location: Developed North Pacific and South Eastern.  
Major undeveloped: Alaska 32 GWe, North Pacific 45 GWe

Potential: 1985, 75 GWe; 2000, 187 GWe. (Note: Must be corrected for siltation of existing reservoirs.)

Primary Requirements: Dam sites, dams, environmental impact studies, turbines, generators.

Means of Implementation: Extend land condemnation powers.

Impacts: Conflicts with scenic river preservation, consumes land, increases energy intensive recreation opportunities.

#### K.1.8 GEOTHERMAL

Type Systems: Hydrothermal, dry steam, magma, hot rock,

Primary Location: Western U. S., Hawaii, Alaska.

Potential: 1985, .7 quad; 2000, 2.5-6 quads. [ERDA-48]

Primary Requirements: Sufficient drilling rigs, improved corrosion resistant materials, improved desalters, improved exploration and drilling technology.

Means of Implementation: Develop realistic leasing rules, extend intangible drilling benefits to geothermal sources.

Impacts: Ties up drilling rigs used for oil and natural gas, H<sub>2</sub>S pollution problems, possible pollution of surface water, possible large demand on water supplies in water scarce regions.

#### K.1.9 WASTE

Type Systems: pyrolysis, digestion, direct incineration, dump site exhaustion

Primary Location: near large municipalities, livestock feed lots, old dump sites.

Potential: 1985, 2.5 quads; 2000, 4.5-9 quads. [ERDA-48]

Primary Requirements: Coordinate waste collection, improve some aspects of technology.

Means of Implementation: Provide explicit, comprehensible information to communities and local utilities about options.

Impacts: particulate emissions and noxious gasses from incineration, water pollution from leaching of residue. Potential fuel shortages resulting from enthusiastic conservation and resultant decline in municipal solid waste.



#### K.1.10 SOLAR THERMAL (CENTRAL)

Type Systems: Geometry -- flat plate, concentrating disks or troughs, reflecting mirror; tracking -- non, single, double; receiver -- distributed, central.

Primary Location: Southwestern U. S. (needs high insolation and clear skies).

Potential: 1985, 100 MWe (.005 quad); 2000,  $10^4$  MWe (.5 quad).

Primary Requirements: Improved storage capability; development of central receivers; development of open cycle and helium cycle plants.

Means of Implementation: Government plus utility backing of prototype and demonstration plants until 1990 (ERDA Plan).

Impacts: Supplies peak and intermediate loads; large land area needed; possible large water requirements in water-scarce regions.

#### K.1.11 SOLAR HEATING/COOLING

Type Systems: Concentrating or flat plate collector; air or water as heat transfer medium; water, rock or eutectic salts as storage medium.

Primary Location: Throughout U. S.

Potential: 1985, 0.3-0.6 quads; 2000, 4.5-9 quads.

Primary Requirements: adequate production of collector components; reduced cost of collectors; improved storage media; higher cost-effectiveness relative to conventional systems; 2-3000 gallons of water per installation.

Means of Implementation: federal assistance in research and technology development; tax incentives for consumers.

Impacts: political, legal, institutional impacts; revision of land use patterns; technical training for building designers; utility companies and energy producers are affected.

## K.1.12 SOLAR PHOTOVOLTAIC

Type Systems: single crystal silicon, polycrystalline silicon, cadmium sulfide, gallium arsenide

Primary location: throughout U. S., best in Southwest.

Potential: 1985, 10MW; 2000, 1400 MW (.07 quad).

Primary Requirements: Sufficient supplies of cadmium and metals for production, improved technology to reduce cost, improved inversion (DC to AC) technology; improved storage capabilities.

Means of Implementation: Silicon refinement industry must be expanded; technological improvements are required.

Impacts: could result in reduced need for fossil fuels; could provide power for peak loads; engineering personnel will represent a high percentage of total manpower requirements compared to related energy industries; solar arrays may not be esthetically pleasing; large tracts of land required for central generation.

## K.1.13 BIOMASS FARM

Type System: Solid wastes, biomass farm, marine farm

Primary Location: Throughout U. S.

Potential: 1985, .082 quad; 2000, .5 quad.

Primary Requirements: capital investment for processing plant, land availability, high water requirements.

Means of Implementation: most technology available; government incentives needed.

Impacts: pesticides required to house and fuel conversion plant; institutional arrangements between city gov'ts'/conversion plants required. Pesticides, fertilizer, and associated water contamination, possible reduction of surface water supply.

K-8  
K.1.14 THERMAL GRADIENTS

Primary Location: Deepwater coastal regions, southern U.S.

Potential: 1985, .005 quads; 2000, .5 quads.

Primary Requirements: Develop technology, provide construction facilities, solve transmission problems, reduce material requirements over present designs.

Means of Implementation: show cost feasibility.

Impacts: Possible thermal effects on ocean currents; possible alteration of marine environments from interchange of plankton layers and pelagic nutrients.

K.1.15 WIND

Primary Location: N.E. coast of U. S., Alaska Coast, Texas Gulf Coast, Hawaii, Great Plains.

Potential: 1985, .15 quad; 2000, 1 quad.

Primary Requirements: Improved anemometry, improved storage systems.

Means of Implementation: government supported wind program.

Impacts: Possible meteorological changes, possible detrimental esthetic effects.

K.1.16 NUCLEAR FISSION:

Type Systems: Light water reactor (LWR), High Temperature gas reactor (HTGR), Breeder reactor.

Location: Areas with sufficient water for cooling

Potential: 1980, 80 GWe; 1985, 190 GWe; Breeder reactor not commercial until 2000.

Requirements: Capital cost reductions, accelerated licensing procedures, greater guarantees of safety, increased labor supply.

Means of Implementation: Reduce 'RED-TAPE' in licensing, standardize design.

Impacts: Waste storage, fuel security, thermal pollution (air and water), large manpower and materials (fuel extraction and processing).

### K.1.17 NUCLEAR FUSION

Type Systems: Magnetic confinement, laser implosion.

Location: As desired.

Potential: minimal by 2000.

Requirements: 1985 -- Test reactors of 1 to 10 MW.  
 1989 -- Experimental Power reactor of 20 to 50 MWe  
 1997 -- Demonstration plant, 500 MWe

Means of Implementation: Primary government funding.

Impacts: many to be determined; problems could arise in social and economic areas from unconstrained supply of energy.

### K.1.18 INTEGRATED SYSTEMS

One of the most interesting of the various diversification schemes is the total-energy systems. At least three variations of this approach are currently under investigations. In one scheme each home or farm is fitted with a hybrid system possibly using basic energy inputs from wind, solar heat, and probably solar/electric cells. One example of this type of total-energy system is currently being developed by Smokey Yunick in Daytona Beach, Florida. The heart of this particular scheme is the use of wind-generated electricity to break down water electrolytically into hydrogen and oxygen for storage and future reforming into methanol, methane, and maybe ammonia. The wind turbine will energize this process days, nights, and weekends. [PS-75,56]

A variety of other similar schemes have been proposed. Some of these even include digesters for utilizing the waste produced by the household and farm.

The second major type of integrated systems is the MIUS concept (Modular Integrated Utility System). This concept, being developed by NASA, utilizes recycling of waste to reduce the requirement for external utility services. A MIUS system would integrate all utility systems into a single function providing electric power, heat, water, and waste collection into an operation which would more completely utilize energy and material inputs than do individual utility functions under present service. Rejected heat in this type of system can be used to provide domestic water heating, comfort heat, and to drive absorption air conditioning systems. Solid waste is recycled and used as fuel to reduce the need for heat input to the generation cycle, thereby reducing the waste disposal requirements. Waste water is also recycled to serve functions which do not require portable water.

NASA reports energy reductions of 33%, reduced water requirement of 9%, reduced liquid waste treatment requirements of 48%, and reduced solid waste of 74% through the use of a MIUS as compared to normal utility services. [Reed-74,93].

A third type of integrated approach is under consideration for municipal use. This concept employs fuel cells in demographically dense urban areas to supply consumers with both electricity and the heat derived from the fuel cell cooling process.

## K.2. REQUIREMENTS FOR DIVERSIFICATION WATER IMPACT STUDY

This section presents data related to the water requirement impact study of chapter 11. The water resource regions are shown in Section K.2.1. The energy resource locations are detailed in Sections K.2.2 to .4. The last sections (K.2.5 to .8) discuss the various water requirements for selected diversification actions.

### K.2.1. WATER RESOURCE REGIONS

The primary Water Resource Regions in which energy extraction is likely to place a heavy demand on the water resources are the Missouri Basin (upper half) and the Upper Colorado. The Lower Colorado and Rio Grande play an important role in solar central generation. Figure K.2.1-1 shows the Water Resource Regions and the locations of critical water related energy problems.

#### Missouri Basin

An estimated 40% of the nation's coal resources lay within the north-western section of the Missouri Basin. Projected coal processing plants and electric generating programs are expected to place a heavy demand on water resources in this area. An eventual maximum of 3 million acre-ft/yr could be made available; one million acre-ft/yr could be supplied now. Such a supply presupposes that necessary legislative action is taken, permits are granted, water is supplied from the Colorado Basin (Green River), and sufficient aqueducts are constructed [PI-74-15].

#### Upper Colorado Basin

The predominant energy source available in the Upper Colorado Basin is oil shale. A second energy source is coal. And to some extent, the oil resources in the region will require water. Water availability in the area depends upon overall supplies ranging from an estimated high of 24 million acre-ft/yr (1917) to about 5.6 million acre-ft/yr (1934).

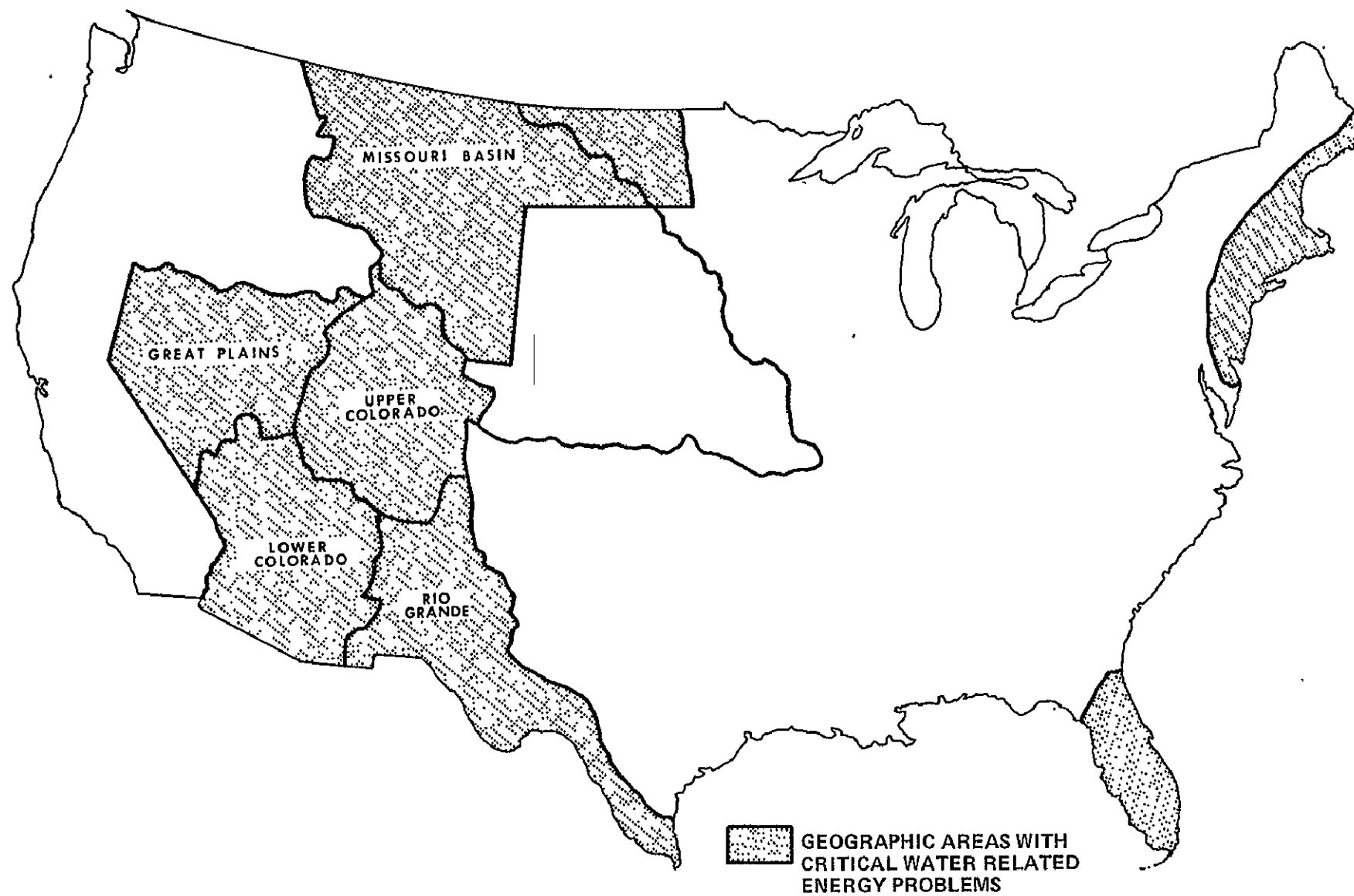


FIGURE K.2.1-1. WATER RESOURCE REGIONS AND GEOGRAPHIC AREAS WITH CRITICAL WATER RELATED ENERGY PROBLEMS

A number of Federal and state laws and international treaties complicate the matter. At present there is slightly over 2 million acre-ft/yr average available for industrial purposes [PI-74-15], but the main difficulty in utilizing this supply is present water-right commitments which tie up 100% of available water. Obtaining access to this supply would be unreasonably costly. Any additional use of water resources in the Upper Colorado area will impact severely on supplies in the Lower Colorado Basin.

#### Lower Colorado

The principal non-fossil energy potential in the Lower Colorado Basin is solar. Oil, natural gas, and to some extent, coal represent the available fossil sources. Water supplied to Arizona, the principal region for concern, is about 2.8 million acre-ft/yr. Most of this is already tied up in urban use, agricultural needs, or commitments to water rights. As a result of increasing demands to the north, the salinity of surface water is increasing, and any energy systems which would require water sources would further deteriorate the supply.

#### Rio Grande

The primary area for concern is southern New Mexico and the southwest corner of Texas. Substantial use is already made in this area of surface water for industrial, agricultural and municipal purposes, and with existing water rights it is unlikely that significant water supplies could be made available for solar central generation without displacing other proposed energy systems. A problem of decreased water quality, similar to that encountered in the Lower Colorado Basin, complicates difficulties.

### K.2.2 COAL RESOURCE LOCATIONS

Coal occurs in large quantities throughout the United States (see Figure K.2.2-1). Primary concentrations of lignite are found in Montana and North Dakota. Bituminous and sub-bituminous coals are located throughout the Rocky Mountain regions. Much of the coal in the western half of the United States is accessible by surface mining techniques.

### K.2.3 OIL SHALE RESOURCE LOCATIONS

While oil shale is found scattered across wide areas of the United States (see Figure K.2.3-1), only one region, roughly the intersection of Wyoming, Colorado and Utah, is considered to have concentrations of oil sufficiently high for commercial development. In this area, the so-called Green River formation, concentrations of oil in shale range as high as 60 bbl/ton with an average of 15-25 bbl/ton.

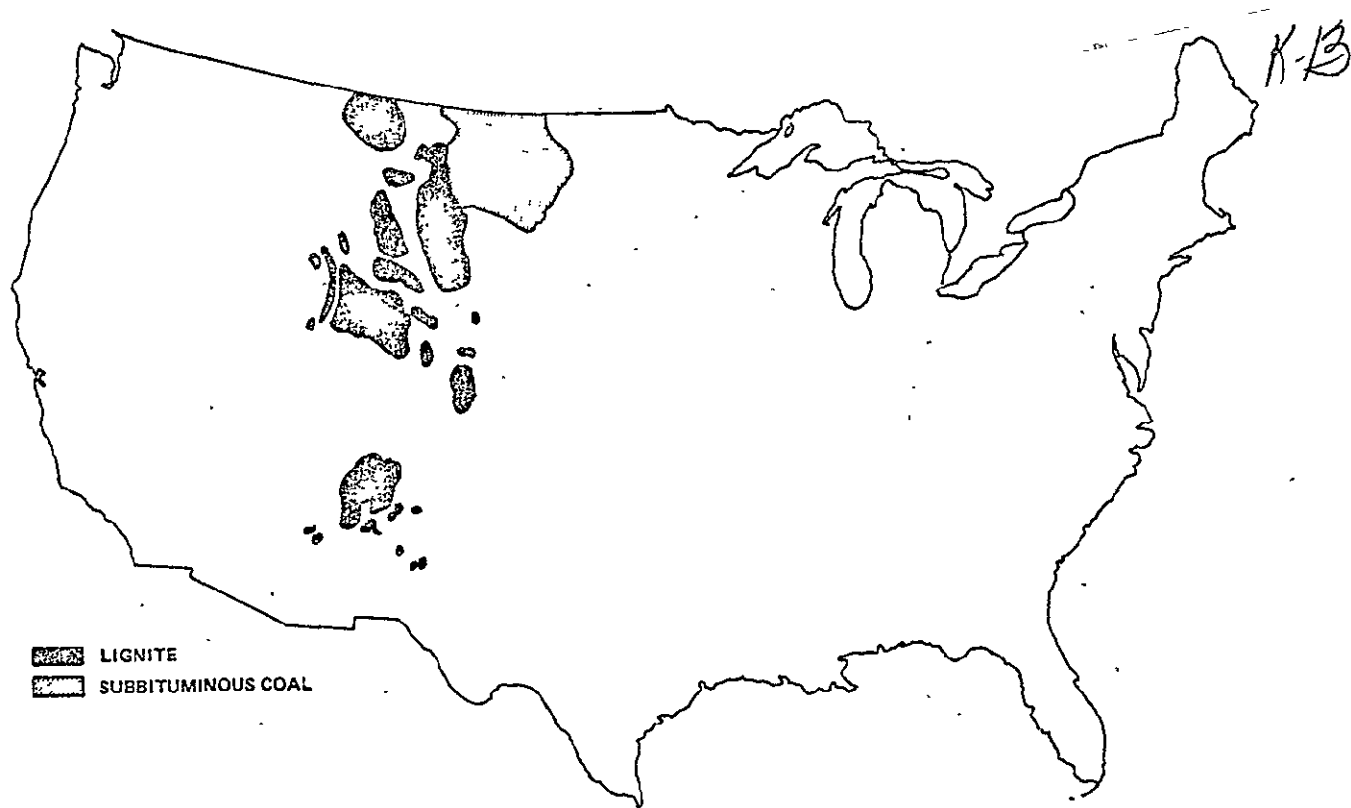


FIGURE K.2.2-1. WESTERN U.S. COAL RESOURCES



FIGURE K.2.3-1. WESTERN U.S. OIL SHALE RESOURCES  
(GREEN RIVER FORMATION)



#### K.2.4 SOLAR CENTRAL RESOURCE LOCATIONS

The region most suitable for solar central generation within the geographic boundaries of the United States is located in southern Arizona and New Mexico. With reduced effectiveness, larger areas including southern California, all of New Mexico and Arizona, and West Texas could be utilized for solar thermal or photovoltaic purposes (see Figure K.2.4-1). Because of the increased frequency of cloud coverage and reduced insolation, it is unlikely that other areas of the country would find solar central power plants feasible.

#### K.2.5 COAL MINING WATER REQUIREMENTS

Coal mining requires water to maintain working conditions, for cleaning coal, for transportation of slurry by pipeline, for on site housekeeping and for revegetation of strip mine coal fields. Except for this last use, surface mines require less fresh water per ton mined than underground mines. It should be noted that revegetation of reclaimed surface mines is a significant water user. Much underground mine water requirements are met with brackish water from dewatering of mines. Table K.2.5-1 provides the basic water use data for coal extraction and cleaning per ton of coal. Estimates of future coal cleaning indicate 75% of Bituminous coal from all regions and 100% of northern Appalachia anthracite will be cleaned. Combining this information with the production percentages in Table K.2.5-2, and the percentage of underground/surface production of Table K.2.5-3 gives water use coefficients for coal production by region in Table K.2.5-4.

#### K.2.6 COAL CONVERSION WATER REQUIREMENTS

Since much of the western low sulfur coal is found in arid regions, water requirements for coal conversion become of primary importance. The ultimate availability of water may in many cases provide the upper bound on coal conversion much more than either coal availability or market requirements. This view must be carefully considered in any orderly developmental plan if the full potential of western coal is to be realized.

A number of proposed coal conversion processes are shown in Table K.2.6-1 together with their corresponding water requirements. Low BTU gas is not economical to transport long distances because of the large associated volumes. Consequently, extremely large quantities will not be produced at a centralized location and severe strains will not be placed on regional water supplies. However, pipeline gas and liquid fuel do present the problems of centralized, large scale processing. Development of these processes should be undertaken with a view of ultimate water availability. Specifically, the HYGAS process

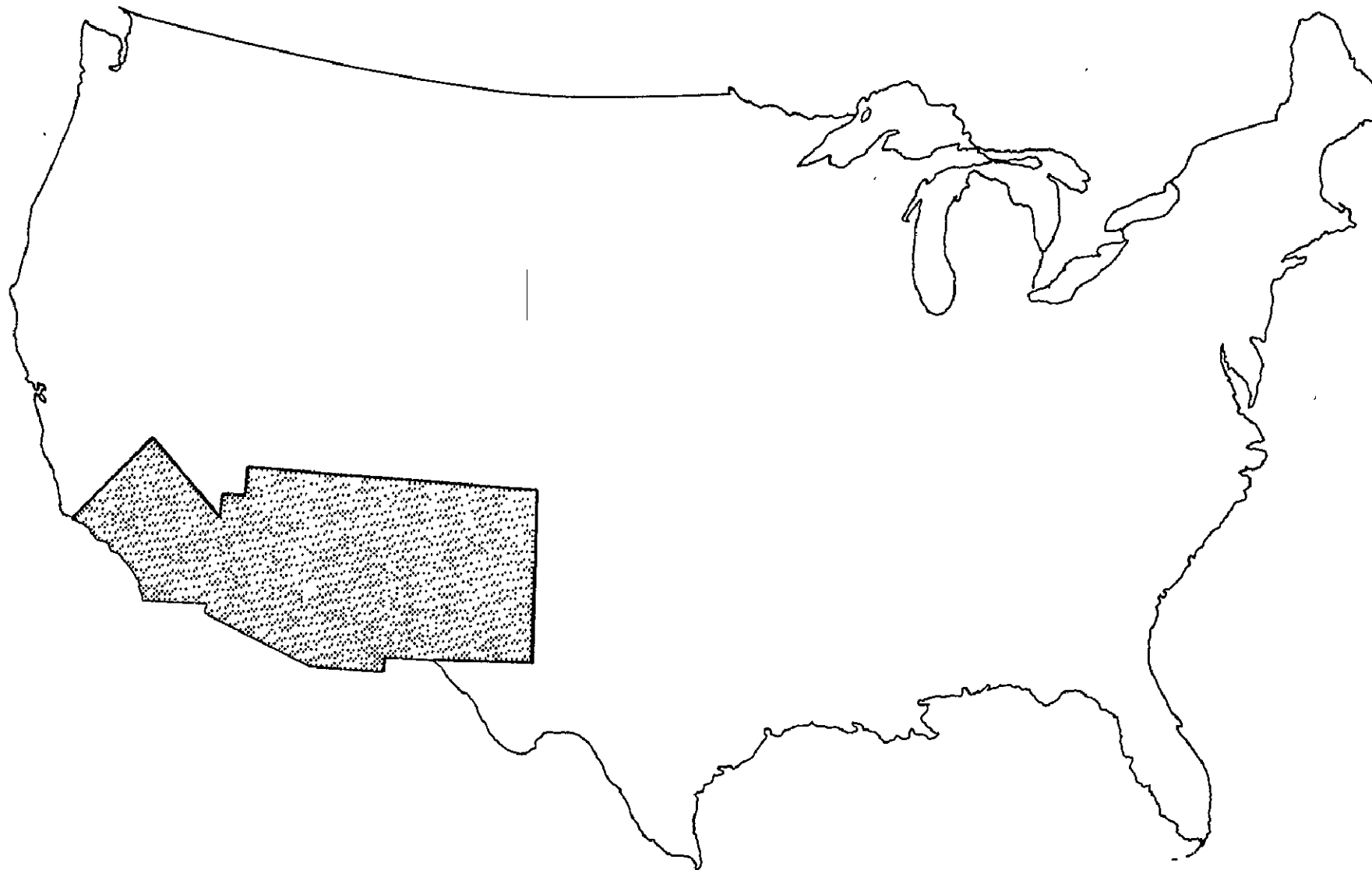


FIGURE K.2.4-1. U.S. SOLAR CENTRAL RESOURCE REGIONS

TABLE K.2.5-1 BASIC WATER USE DATA FOR COAL EXTRACTION AND CLEANING

	Underground	Surface
Water Withdrawal per ton mined	15.0	4.0
Water Consumption per ton mined	15.0	4.0
Water Withdrawal per ton wasted	524.	524.
Water Consumption per ton wasted	8.0	8.0

TABLE K.2.5-2 COAL PRODUCTION PERCENTAGES BY TYPE FOR THE  
COAL PRODUCING REGIONS

Coal Region	Percent Bituminous	Percent Sub-bituminous/Lignite	Percent Anthracite
1	95	0	5
2	100	0	0
3	100	0	0
4	0	100	0
5	0	100	0
6	38	62	0
7	0	100	0

TABLE K.2.5-3 PERCENTAGES OF COAL PRODUCTION WHICH IS PRODUCED THROUGH SURFACE AND UNDERGROUND MINING

Coal Region	Percent Underground	Percent Surface
1	69.1	30.9
2	52.4	47.6
3	51.5	48.5
4	0.0	100.0
5	1.8	98.2
6	69.9	30.1
7	0.9	99.1

TABLE K.2.5-4 WATER-USE COEFFICIENTS FOR COAL PRODUCTION BY COAL PRODUCING REGION

Coal Region	Withdrawal Water-Use Coefficient (gal/ton)	Consumptive Water-Use Coefficient (gal/ton)
1. Northern Appalachia	430.8	18.0
2. Southern Appalachia	402.8	15.8
3. Midwestern	402.7	15.7
4. Gulf	4.0	4.0
5. Northern Great Plains	6.0	6.0
6. Rocky Mountain	210.8	14.7
7. Pacific Coastal	4.1	4.1

TABLE K-2.6-1 COAL CONVERSION WATER REQUIREMENTS [PI-74-3, 110]

Process	$\frac{\text{Acre-Ft/yr}}{10^9 \text{ BTU/Day}}$	$\frac{\text{Acre-ft}}{\text{Quad}}$
<u>Low BTU Gas:</u>		
Atmospheric pressure fixed bed	18	$.049 \times 10^6$
Elevated Pressure Entrained bed	98	$.269 \times 10^6$
Lurgi	57	$.156 \times 10^6$
<u>Pipeline Gas:</u>		
Synthetic	104	$.285 \times 10^6$
Hygas	32	$.088 \times 10^6$
Lurgi	120	$.329 \times 10^6$
<u>Liquid Fuel:</u>		
SRC	30	$.082 \times 10^6$
Synthoil	56	$.153 \times 10^6$
Fisher-Tropsch (Parsons)	59	$.016 \times 10^6$
Fisher-Tropsch (USBM-PEG)	134	$.367 \times 10^6$

and the Fisher-Tropack (Parsons) processes should receive major consideration in present R and D programs. In addition to water required by the process plants, the increased associated population will place an additional strain on water availability. The total manpower requirements for each advanced process are not well defined at this time, but are assumed to be similar to those for existing Lurgi units. This adds an additional requirement of .03 million acre/feet/year for each quad of synthetic fuel. Comparing total uncommitted water resources in each water area given in Section K.2.1 to total water requirements for each process indicates the potential for synthetic fuel development in each region. Care must be exercised however in such an analysis since the situation is dynamic. Additional reservoirs are planned in certain areas which will increase resources, while expanding agricultural irrigation will increase demand.

#### K.2.7

The five major methods currently under study (see Table K.2.7-1) for the extraction of crude oil from shale are underground mining with surface retorting; surface mining with surface retorting; in situ; modified in situ [PI-74-9]; and an alternative modified in situ (essentially the Garrett process). Demand for external water in each is low; it is expected that about 2% of the total water consumed will have to be provided from external sources. Primary water consumption is associated with urban and revegetation requirements.

#### K.2.8 SOLAR CENTRAL WATER REQUIREMENTS

The two basic methods of producing electricity directly from solar insolation involve either photovoltaic arrays (see K.1.12) or solar thermal conversion (see K.1.10).

The water requirements for photovoltaic conversion are practically nil unless the plant operating personnel are considered--even then water is not much of a factor unless industries are encouraged to move into the area. Under some conditions, photovoltaic arrays may be cooled by circulating water to keep the cells below some maximum operating temperature. This cooling water would be in a closed loop and would not involve any water beyond initial charging of the loop. Dry cooling would be appropriate for the heat rejection.

The water requirements for a solar thermal plant could pose more of a restriction. For a 100 MWe solar thermal power plant, approximately 200 MW (thermal) must be rejected to the environment. For the conventional steam cycle type plant, there are three possible methods of rejecting this heat:

TABLE K.2.7-1 WATER CONSUMED FOR VARIOUS RATES OF SHALE OIL PRODUCTION <sup>1/</sup> (ACRE/FEET/YEAR).

	Shale Oil Production (Barrels per day)					
	50,000 Underground	100,000 Surface Mine	50,000 In Situ	50,000 Modified In Situ	50,000 Alternative In Situ	2/
<b>PROCESS REQUIREMENTS</b>						
Mining and Crushing	370- 510	730 - 1,020	--	170- 230		Not available
Retorting	580- 730	1,170 - 1,460	--	260- 330	--	
Shale Oil Upgrading	1,460-2,190	2,920 - 4,380	1,460- 2,220	1,460-2,220		1,460 - 2,220
Processed Shale Disposal	2,900-4,400	5,840 - 8,750	--	1,300-2,070		700 - 1,000
Power Requirements	730-1,020	1,460 - 2,040	730- 1,820	730-1,660		Not available
Revegetation	0- 700	0 - 700	0- 700	0- 700		0 - 700
Sanitary Use	20- 50	30 - 70	20- 40	20- 40		10 - 25
Subtotal	6,060-9,600	12,150 -18,420	2,210- 4,780	3,440-7,250		
External Water Consumed <sup>3/</sup>	121- 892	243 - 1,068	44- 797	69- 845		0 - 700
<b>ASSOCIATED URBAN</b>						
Domestic Use	670- 910	1,140 - 1,530	720- 840	710- 850		340 - 460
Domestic Power	70- 90	110 - 150	70- 80	70- 80		35 - 70
Subtotal	740-1,000	1,250 - 1,680	790- 920	780- 930		375 - 530
GRAND TOTAL	6,800-10,600	13,400 -20,100	3,000- 5,700	4,220-8,180		
Total External Water Consumed	861- 1,892	1,493 - 2,748	834- 1,717	849-1,775		375 - 1,230

<sup>1/</sup> Adopted from Project Independence [PI-74-9]<sup>2/</sup> Based on information supplied by Occidental Shale Oil Co. [Ridley-75]<sup>3/</sup> Assuming 2% external water required for all but alternative in situ.

ORIGINAL PAGE IS  
OF POOR QUALITY

TABLE K.2.8-1. SOLAR CENTRAL WATER REQUIREMENTS BASED ON 100 MWe PLANT

Type Plant (100 MWe Base)	Once-through Cooling (66,000 gal/min) <sup>d</sup>	Wet Cooling Tower (4000 gal/min) <sup>d</sup>	Dry Cooling Tower (nil)
PHOTOVOLTAIC: . air cooled . water cooled	N/A N/A	N/A N/A	N/A nil
SOLAR THERMAL: <sup>a</sup> . steam cycle . open air cycle . helium cycle	53,000 acre-feet/yr <sup>b</sup> N/A --	3,200 acre-feet/yr <sup>3</sup> N/A --	nil N/A nil

a. Plant operates at intermediate load (.5 load factor)

b. Assuming 10% increased evaporation--5,300 acre-feet consumed/yr

c. Assuming 100% evaporation rate--3300 acre-feet consumed/yr

d. [PI-74-10]

Once-through (water) condenser cooling

Wet cooling tower (water and air)

Dry cooling tower (air)

The water requirements for each of these methods is illustrated in Table K.2.8-1.

Due to the fact that solar thermal plants are being planned for the southwestern United States where water is scarce, several investigations are being made of power cycles which do not require water cooling or the use of the relatively expensive dry cooling towers. The open air cycle and the helium gas cycle are candidates [BOS-75]. Also, the concept of using the waste heat for desalinization of brackish water has been proposed as being an added benefit to the southwestern United States in addition to the power generation. In fact, the fresh water produced may be of equal or greater value than the power in some regions.

### K.3 ASSESSMENT OF ENERGY SOURCE IMPACTS IN WATER SCARCE REGIONS

This section is an elaboration on the impacts covered by the water requirements for the diversification energy sources (see Chapter 11). The organization of this impact study is shown on the systems diagram, Figure K.3-1. The requirements necessary to satisfy the objective of identifying water requirement impacts were to:

Identify water availability (see K.2.1)

Identify unit water requirement for each energy source (see K.2.5-8)

Identify geographic regions for implementing each energy source (see K.2.2-4)

Identify base case for energy usage

Assess impacts

A complete assessment of the water requirements and impacts of alternative systems would require substantially more information than is now available from any source. In fact, the process of information acquisition could continue indefinitely. Nevertheless, on the basis of information available at present, some alternatives seem to be more viable than others.

#### K.3.1 INCREASED WATER SUPPLIES

A variety of recommendations have been made to augment the water resource base in the Western United States. These recommendations, some of which are under study at the present, include:



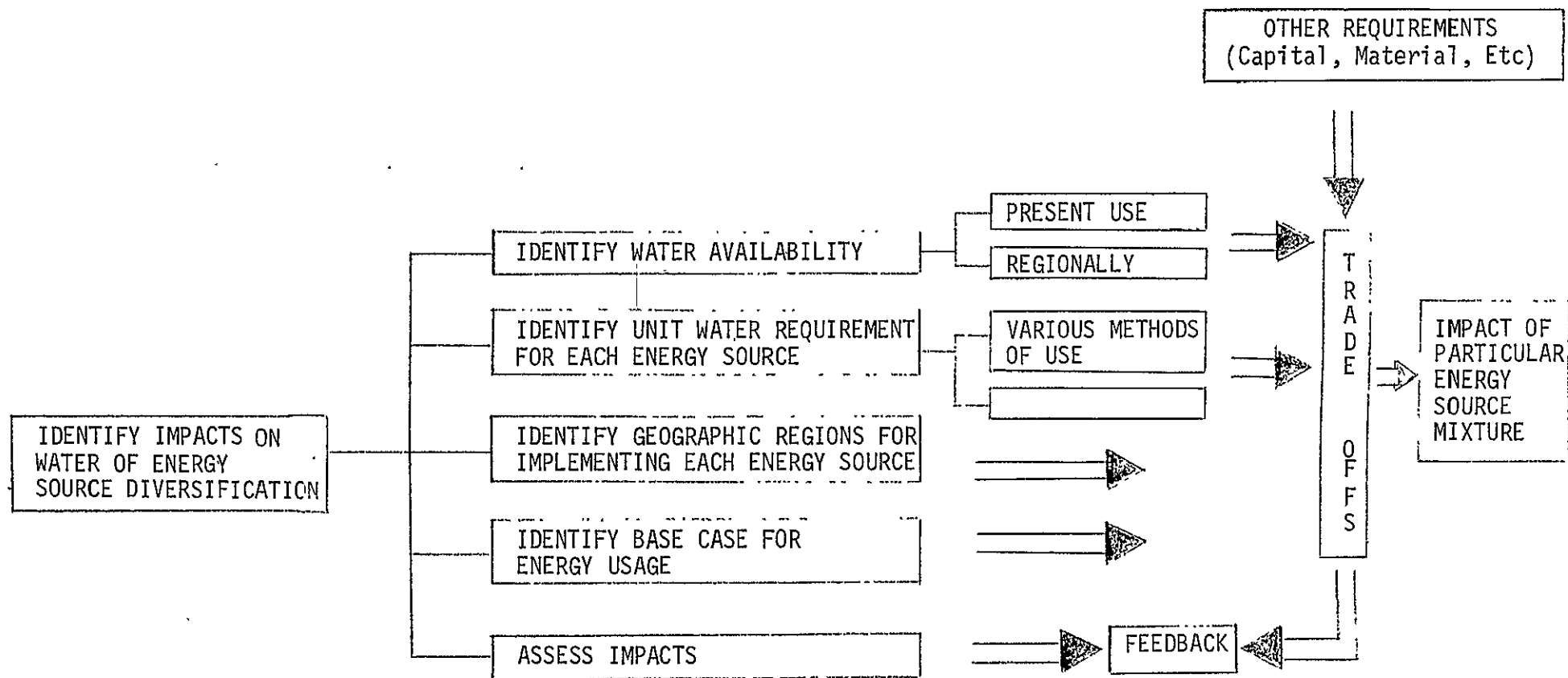


FIGURE K.3-1. SYSTEMS DIAGRAM FOR IMPACT ANALYSIS OF WATER REQUIREMENT

Diversion of water from California to the Southern Colorado Basin.

Transporting water from the Missouri River to Wyoming for coal gasification.

Diverting significant amounts of water moderate distances for industrial purposes.

Weather modification to increase rainfall in Missouri and Upper Colorado regions.

Each of these proposals would seem to require intensive study. Both relocation and weather modification have a large potential for detrimental environmental impacts. Apart from the long term terrestrial changes likely to accrue from either plan, weather modification may result in meteorological changes elsewhere.

### K.3.2 OIL SHALE

None of the processes for extracting oil from shale require unreasonable amounts of external water. Each, however, will require substantial water for revegetation, land reclamation and associated urban development resulting from increased population. In-situ processes will require generally less external water and hence are more desirable; if costs are comparable, in situ is to be preferred.

### K.3.3 COAL

Synthetic fuels from coal are generally produced by water intensive processes. Coal mining may also be water intensive in the coal preparation stage, but it is believed that this problem may be overcome. Water is generally scarce in all of the coal areas of the Great Plains. While water might be transported from the Upper Missouri Basin into eastern Wyoming, it is not considered economically feasible to run pipelines into the more southern coal fields. For this reason development of gasification or liquification plants within the Upper Colorado Basin and in nearby arid regions is not deemed attractive.

### K.3.4 SOLAR

Solar central generating systems are likely to be located in New Mexico or Arizona, regions where there is essentially no water available. Several alternatives exist to typical, water cooled installations: air cooling, utilizing waste heat to desalt cooling water, or installing photovoltaic systems. All of the alternatives to water cooling involve extra expense, but not so much as to rule out the possibility of using solar central.

### K.3.5 OTHER CONSIDERATIONS

Diversion of water to coal production has potential repercussions on other water users. Conflict with water needs for existing and future oil and gas production and other mineral activities is one. Molybdenum, uranium and precious metals are presently produced in the region. Uranium, in fact, is a primary water user, consuming approximately 200 gallons of water per pound of  $U_3O_8$  produced. Since New Mexico, Utah, Colorado, and Wyoming now produce about 88% of the nation's uranium, an expected U. S. nuclear capacity of 190 GWe in 1985 will require  $33 \times 10^6$  gallons water per day from these states.

Municipalities are another claimant for water. Large amounts of water on the western slope are committed to California cities and to farm irrigation at present. Then too, if the natural water table is affected, regional lumber and livestock production would suffer. Of no little concern is maintaining the region's natural environment as it concerns outdoor recreation and as it concerns wildlife preservation. Water consumption could change that as well.

### K.4 ERDA PLANS AND BUDGET

Public Law 93-577 calls for RD and D in the areas of energy supply to:

Accelerate the commercial demonstration of technologies for producing substitutes for natural gas, including coal gasification.

Accelerate the commercial demonstration of technologies for producing syncrude and liquid petroleum products from coal.

Accelerate the commercial demonstration of geothermal energy technologies.

Demonstrate the production of syncrude from oil shale by all promising technologies including in situ technologies.

Explore secondary and tertiary recovery of crude oil.

Demonstrate the economic and commercial feasibility of solar energy for residential and commercial applications.

Accelerate the commercial demonstration of environmental control systems for energy technology developed under this Act.

Investigate the feasibility of tidal power for supplying electrical energy.

Commercially demonstrate advanced solar energy technologies

Determine the feasibility of production of synthetic fuels such as hydrogen and methanol.

Demonstrate the commercial feasibility of fuel cells for central station electric power generation.

Determine the economic and commercial viability of in situ coal gasification.

ERDA responded to Public Law 93-577 with its first National Plan, ERDA-48, which appears to manifest an intention toward diversification. The philosophy in the plan appears to be one of exploration on a broad front so as to ensure maximum flexibility for future energy choices -- to seek to clarify uncertainties and ascertain the feasibility of a variety of sources in terms of socio-economic, institutional, resource and environmental constraints.

ERDA sees the need for five major changes in the nature and scope of the nation's RD and D program [ERDA 48-75]:

Emphasis on overcoming the technical problems inhibiting expansion of high leverage existing systems -- notably coal and light water reactors.

Achieving an expansion requires the solution of several critical problems involving operational reliability and acceptable environmental impact.

An immediate focus on conservation efforts.

These efforts implement first generation existing technology, extend this technology with improved capabilities, demonstrate its viability and widely disseminate the results.

The primary targets are automotive transportation, buildings and industrial processes.

Acceleration of commercial capability to extract gaseous and liquid fuels from coal and shale.

A two-pronged effort is needed to achieve this objective. Existing technologies must be implemented as soon as possible to gain needed experience with large scale synthetic fuel production. A Synthetic Fuels Commercialization program is

now being developed to implement the President's synthetic fuels' goal announced in the 1975 State of the Union Message. Also required is aggressive pursuit of parallel efforts, now underway, to develop a more efficient generation of plants with lower product costs and less environmental impact.

Inclusion of the solar electric approach among the "inexhaustible" resource technologies to be given high priority.

The technologies for producing essentially inexhaustible supplies of electric power from solar energy will be given priority comparable to fusion and the breeder reactor.

Increased attention to under-used new technologies that can be rapidly developed.

The technologies that are close to implementation and promise a significant impact for the mid-term and beyond are principally solar heating and cooling and the use of geothermal power.

In ERDA-48 we appear to have an institutional commitment to a policy of diversification in energy supply. However, comparison of ERDA's resource allocation (budget) with their RD and D plans suggests some discrepancy. The National Conference of State Legislatures (NCSL) in their July 11 and July 25, 1975 energy newsletters presents an ERDA Budget request (Table K.4-1). Nuclear accounts for 81 percent of this budget. Editors of the NCSL newsletters remark on the difficulty of aggregating ERDA's budget to that which is portrayed in Table K.4-1. Even with the possibility of some noise in the data, NCSL suggests that if ERDA were to implement their research plan it would imply some rather radical budgetary modifications. Perhaps some of the difference between budget and research plans can be explained by the following statement taken from page S-6 of ERDA-48,

"It should be noted that outlays for Federally supported programs may not necessarily conform to the national ranking developed here. This is because many of the technologies will be developed in the private sector and there are differences in the scope of the program effort and the extent of development required."

Further study is needed to more clearly see how strong ERDA's commitment becomes in the future to the pursuit of a broad policy of diversification at the supply end. It is perhaps a bit precarious to make judgements based on ERDA's first budget. As has been pointed out several times, in beginning to develop a previously undeveloped research and development area, it is not possible to both instantaneously use and efficiently use an infinite amount of money.

TABLE E.4-1 ERDA BUDGET REQUESTS (MILLIONS OF DOLLARS) [NCSL-75]

PROGRAMS	OPERATING EXPENSES FY76	CAPITAL EXPENSES FY76	TOTAL FY76	PERCENT OF ENERGY BUDGET
Coal	279.5	20.0	299.5	12.0
Petroleum & Gas	23.7		23.7	0.9
Oil Shale	8.1		8.1	0.3
Solar	57.1		57.1	2.3
Geothermal	28.3		28.3	1.1
Conservation	32.2		32.2	1.3
Advanced Systems	23.2		23.2	0.9
Nuclear <sup>1</sup>	1416.8 <sup>3,4</sup>	609.8	2026.6	81.1
Sub Total	1868.9	629.8	2498.7	100.0
Physical Research	312.5			
Nuclear;				
Space & Naval	217.1			
Weapons	938.4	264.9	2475.6	
Environment, Safety <sup>2</sup>	197.7	(Total)	(Total)	
Miscellaneous	545.0			
Total Budget	4079.6	4974.3	4974.3	

<sup>4</sup>Includes approximately \$575 million which is received by the U. S. General Treasury from sale of nuclear materials. These dollars should be included in an estimate of ERDA's resource allocation but should not be included in an estimate of the government's net nuclear expenditures

<sup>3</sup>Includes less than \$200 million weapons

<sup>2</sup>Primarily nuclear related

<sup>1</sup>Excluding space and weapons

## APPENDIX L. CITIZENS' ACTIONS

### A Historical Perspective of Energy Consumption

The first source of energy exploited by the earliest culture systems was, of course, the energy of the human organism itself. The amount of power generated by an average adult is small -- one-tenth of one horsepower. Considering women, children, the sick, aged, and feeble, the average power resources may be estimated at about one-twentieth horsepower per capita. It is understandable then, that the earliest cultures of mankind, dependant as they were upon the energy resources of the human body, were meager, crude, and simple, as indeed they had to be.

If culture was to advance beyond the limits of the energy resources of the human body, it had to harness additional amounts of energy by tapping natural resources in some new form. Fire was used in early cultures in providing warmth in cooking and in frightening wild beasts, but only as a substitute for muscle power in the manufacture of dugout canoes from hollowed out tree trunks. Fire, along with water and wind, was utilized as a source of energy only to a very limited extent.

Another source of energy available to and eventually harnessed by primitive man was that of plants and animals. After some million years of human development, certain plants were brought under cultivation and various animal species were controlled through domestication. As a result, the energy resources for cultural advancement were greatly increased. Cultivation, fertilization, and irrigation greatly increased the yield per unit of human labor energy. Likewise, domestication of animals allowed people to subsist on their herds and flocks. As a result, within a few thousand years of these advancements, the great civilizations of antiquity (Egypt, Mesopotamia, India, China: in the New World, Mexico, Middle America, the Andean Highlands) came into being. Great empires, nations, and cities took the place of villages, tribes, and confederacies as a consequence of this Agricultural Revolution.

It is interesting that, after this period of rapid growth, the upward curve of cultural progress levelled off. The peaks of cultural development in Egypt, India, China, and Mesopotamia were reached prior to 1000 B.C., and from that time to the beginning of the Fuel Age (about A.D. 1800) no culture of the Old World surpassed, in any profound and comprehensive way, the highest levels achieved during this period.

The Fuel Age emerged because of man's success in harnessing additional energy by tapping the forces of nature in new forms. Energy, in the form of coal, oil and gas, was harnessed by means of steam and internal combustion engines. By tapping the vast deposits of coal, natural gas, and oil, a tremendous increase in the amount of energy available for culture building was quickly effected. The consequences of the Fuel Revolution were in general much like those of the Agricultural Revolution -- an increase in population, larger political units, bigger cities, and a rapid development of the arts and sciences; in short, a rapid and extensive advancement of culture as a whole.

In summary, the progress and development of culture are affected by the improvement of the mechanical means with which energy is harnessed as well as by increasing the amount of energy employed.



## APPENDIX M. SEMINAR SUMMARIES

The many speakers who conducted seminars for the 1975 NASA/ASEE Faculty Fellowship Program in Systems Engineering Design at the Marshall Space Flight Center, Huntsville, Alabama, which was directed by Auburn University, provided invaluable resource material for the 21 professors who participated in the program. The summaries given in this appendix are the paraphrased remarks of each speaker and in some instances the opinions or impressions of the faculty fellows are interwoven into the fabric of the summary.

Due to the length (80 pages) of the summaries, Appendix M is available separately, in limited numbers, from

Engineering Extension Service  
Auburn University  
Auburn, Alabama 36830

Listed below are the speakers, their affiliation, and the title of their talk. The speakers are arranged in chronological order.

Roger W. Sant, Federal Energy Administration  
"Energy Conservation Programs in FEA"

W. R. Finger, Exxon Company  
"Energy Scenarios and Conservation Implementation"

Anthony J. Parisi, Business Week  
"Energy as Seen From a Business Perspective"

Wilson Harwood, Stanford Research Institute  
"The Middle East - Where the Oil Is"

Jack E. Snell, National Bureau of Standards  
"Energy Conservation and NBS"

William Prengle, Jr., University of Houston  
"Potential for Energy Conservation in Industrial Operations"

Sydney Howe, Center for Growth Alternatives  
"Energy Conservation Scenarios"

A. W. Wortham, Federal Energy Administration  
"Technological Approaches to Energy Conservation"

Stan A. Trumbower, Westinghouse Electric Corporation  
"Managing Your Piece of the Energy Crisis"

John Blackstone, State of Alabama  
"Evaluation of Ford Foundation Report"

Walter F. Spiegel, W. F. Spiegel, Inc.  
"ASHRAE Studies of Energy Conservation"

K-2

Alan Barton, Alabama Power Company  
"Energy Conservation From a Power Company Perspective"

George Cunningham, Energy Research and Development Administration  
"Nuclear Reactor R & D"

Larry Stewart, Energy Research and Development Administration  
"Energy Conservation in ERDA"

Ed Hudspeth, Alabama Energy Management Board  
"The State and National Energy Picture"

Vernon Rydbeck, General Electric Company  
"Electric Power, Energy and Environment"

William P. Miller, Jr., The American Society of Mechanical Engineers  
"Overview of Energy on Capitol Hill"

Arnold Safer, Irving Trust Company  
"Economic Aspects of Energy Crises "

Grant P. Thompson, Environmental Law Institute  
"Legal and Legislative Aspects of Energy Conservation"

Arnold Windman, Syska and Hennessy  
"Engineering Consultants and Conservation"

Barry Hyman, Senate Commerce Committee  
"Energy Conservation Legislative Proposals"

John P. Eberhard, AIA Research Corporation  
"Energy Conservation in Buildings"

Ralph Rotty, Institute for Energy Analysis  
"Energy and Climate--A Case for Conservation"

Tim Nulty, United Auto Workers  
"Labor and Energy Conservation"

David MacFadyen, Technology and Economics, Inc.  
"Technology Transfer and NASA"

Laura Nader, University of California  
"Cultural Aspects of Energy Conservation"

Joseph F. Coates, U. S. Congress  
"Introduction to Technology Assessment"

Virginia Garrett, Montgomery Citizens Action Committee  
"Private Intervention for Energy Conservation"

Byron R. Brown, Jr., E. I. DuPont Company  
"Energy Conservation in Industry"

Richard D. Wood, NASA  
"New Propulsion Systems"

J. N. Foster, Marshall Space Flight Center  
"The MSFC Energy Conservation Program"

R. J. Raudebaugh, United States National Committee  
"The World Energy Conference"

Robert G. Metke, Browns Ferry Nuclear Power Station  
"Tour and Overview of the Plant"

John Vanston, University of Texas  
"The University Role in Energy Conservation"

Douglas Alexander, NASA/Ames Research Center  
"Energy and Technology Assessment"

ORIGINAL PAGE IS  
OF POOR QUALITY

## APPENDIX N. FEDERAL AND STATE ENERGY LEGISLATION

This appendix contains Federal and State energy legislation, both proposed and enacted. Section N.1 is a listing of Federal energy-related legislation as of June 1975 with a brief description of each bill. This listing was compiled by Mr. Bill Miller, Washington Representative of the American Society of Mechanical Engineers.

Section N. 2 is a listing of State energy legislation or actions as of June 1975 as compiled by Mr. Grant Thompson, Environmental Law Institute, Washington, D. C.

## N.1 FEDERAL ENERGY-RELATED LEGISLATION (as of June 1975)

Automobiles

## S. 783 Research--ground propulsion systems

By Domenici, Baker and Glenn

To authorize a federal program of research and demonstration in connection with ground propulsion systems. (To Commerce.)

Status: Hearing in Senate 3/12/75

## S. 1120 Excise taxes--automobiles--fuel consumption rate

By Case

To amend the Internal Revenue Code of 1954 to impose an excise tax on passenger automobiles, based on fuel consumption rates and to allow a credit for the purchase of passenger automobiles which meet certain standards of fuel consumption. (To Finance.)

Status:

## S. 1508 See Consumer Legislation

## S. 1518 Authorizations--fiscal 1976 and 1977--motor vehicle economy

By Moss(Utah), Magnuson, Hart(Mich.) and Hartke

To amend the Motor Vehicle Information and Cost Savings Act (15 U.S.C. 1901 et seq.) to authorize additional appropriations, to establish fuel efficiency demonstration projects, to provide additional enforcement authority for the odometer antitampering provisions. (To Commerce.)

Status:

## S. 1623 Economy--Basic Price Index

By Nelson, Javits, Mondale and Laxalt

To direct the Secretary of Labor to change the name of the Wholesale Price Index to the Basic Price Index. (To Post Office and Civil Service.)

Status:

## H.R. 3195 Income tax credits--motor vehicles--1975 and 1976

By Annunzio

To amend the Internal Revenue Code of 1954 to provide a credit against tax related to the purchase of certain new motor vehicles during 1975 and 1976. (To Ways and Means.)

Status:

## H.R. 3608 Excise taxes--automobiles--weight

By Roncalio

To amend the Internal Revenue Code of 1954 to impose a temporary excise tax on passenger motor vehicles based on horsepower, to amend the National Traffic and Motor Vehicle Safety Act of 1966 to prohibit the manufacture of passenger motor vehicles which do not comply with certain limitations with respect to weight, fuel economy, and horsepower. (To Ways and Means and Interstate and Foreign Commerce.)

Status:

## H.R. 3877 Excise taxes--motor vehicles--fuel consumption rate

By Obey

To provide for the conservation of petroleum and

other natural resources by imposing an excise tax on the sale of certain automobiles and granting a tax credit on the sale of certain automobiles according to the rate at which such automobiles consume fuel. (To Ways and Means.)

Status:

## H.R. 4000 Air pollution control--emission standards--motor vehicles

By Fiegle

To amend federal statutes regulating automobile emissions and automobile safety and to provide certain rules with respect to automobile fuel efficiency to permit the manufacture of safe, non-polluting, fuel efficient automobiles. (To Interstate and Foreign Commerce.)

Status:

## H.R. 4320 Excise taxes--motor vehicles--fuel consumption rate

By Pike, Obey and Spellman

To provide for the conservation of petroleum and other natural resources by imposing an excise tax on the sale of certain automobiles and granting a tax credit on the sale of certain automobiles according to the rate at which such automobiles consume fuel. (To Ways and Means.)

Status:

## H.R. 4363 Energy--fuel economy--motor vehicles

By Ashley

To regulate commerce and conserve gasoline by improving motor vehicle fuel economy. (To Interstate and Foreign Commerce.)

Status:

## H.R. 4432 Excise taxes--automobiles--fuel consumption rate

By Litton and Santini

To provide an excise tax on every new automobile in an amount relating to the portion of such automobile's fuel consumption rate which falls below certain standards, to provide an Energy Research and Development Trust Fund. (To Ways and Means.)

Status:

## H.R. 4519 Excise taxes--automobiles--fuel consumption rate

By Jeffords, Wilson(Texas), Coughlin, Pressler and Pattison

To amend the Internal Revenue Code of 1954 to impose an excise tax on passenger automobiles based on fuel consumption rates and to allow a credit for the purchase of passenger automobiles which meet certain standards of fuel consumption. (To Ways and Means.)

Status:

## H.R. 4729 Excise taxes--automobiles--fuel consumption rate

By Vanik, Burke(Mass.), Fraser, Harris, Ottinger, Quie, Treen, Wirth and Wolff

To amend the Internal Revenue Code of 1954 to provide for a tax on every new passenger automobile based on its fuel consumption rate, to provide for public disclosure of the fuel consumption rate of every such automobile. (To Ways and Means.)

Status:

H.R. 5085 Excise taxes--automobiles--fuel consumption rate

By Jeffords and Cleveland

To amend the Internal Revenue Code of 1954 to impose an excise tax on passenger automobiles based on fuel consumption rates and to allow a credit for the purchase of passenger automobiles which meet certain standards of fuel consumption. (To Ways and Means.)

Status:

H.R. 5423 Energy--fuel economy--motor vehicles  
By Anderson(Calif.)

To regulate commerce and conserve gasoline by improving motor vehicle fuel economy. (To Interstate and Foreign Commerce.)

Status:

H.R. 5470 Research--electric vehicles

By McCormack, Brown(Calif.), Teague, Mosher and Goldwater(Calif.)

To authorize in the Energy Research and Development Administration a federal program of research, development, and demonstration designed to promote electric vehicle technologies and to demonstrate the commercial feasibility of electric vehicles. (To Science and Technology.)

Status:

H.R. 5784 Air pollution control--emission standards--motor vehicles

By Riegle, Cleveland, Daniel(W.C.-Va.), Diggs, Leggett, Whitehurst and Wilson(Tex.)

To amend Federal statutes regulating automobile emissions and automobile safety and to provide certain rules with respect to automobile fuel efficiency to permit the manufacture of safe, non-polluting, fuel efficient automobiles. (To Interstate and Foreign Commerce.)

Status:

H.R. 5817 Excise taxes--motor vehicles--fuel consumption rate

By Litton and Harrington

To provide an excise tax on every new automobile in an amount relating to the portion of such automobile's fuel consumption rate which falls below certain standards, to provide an Energy Research and Development Trust Fund. (To Ways and Means.)

Status:

H.R. 5844 Excise taxes--motor vehicles--horsepower

By Evans(Colo.)

To amend the Internal Revenue Code of 1954 to impose a temporary excise tax on passenger motor vehicles based on horsepower, to amend the National Traffic and Motor Vehicle Safety Act of 1966 to prohibit the manufacture of passenger motor vehicles which do not comply with certain limitations with respect to weight, fuel economy, and horsepower. (To Ways and Means, and Interstate and Foreign Commerce.)

Status:

H.R. 6031 Research--electric vehicles

By McCormack, Brown(Calif.), Teague, Mosher, Goldwater(Calif.), Hochler(W. Va.), Bell, Fuqua, Symington(J.W.-Mo.), Winn, Roe, Thornton, Myers(Pa.), Scheuer, Emery, Ottinger, Hayes(Ind.), Harkin, Dodd, Blouin, Hall, Lloyd(Tenn.), Pepper and Yatron

To authorize in the Energy Research and Development Administration a federal program of research, development, and demonstration designed to promote electric vehicle technologies and to demonstrate the commercial feasibility of electric vehicles. (To Science and Technology.)

Status:

H.R. 6198 Research--electric vehicles

By McCormack, Brown(Calif.), Teague, Mosher, Goldwater(Calif.), Milford, Abdnor, Byron, Duncan(Tenn.), Ford(Tenn.), Grassely, Guyer, Harrington, Hicks, Jenrette, Koch, Lujan, McCloskey, Mazzoli, Nix, Pritchard, Rodino, Rosenthal, Sisk and Studds.

To authorize in the Energy Research and Development Administration a federal program of research, development and demonstration designed to promote electric vehicle technologies and to demonstrate the commercial feasibility of electric vehicles. (To Science and Technology.)

Status:

H.R. 6315 Research--electric vehicles

By McCormack, Brown(Calif.), Teague, Mosher, Goldwater(Calif.), Andrews(N.D.), Cleveland, Cotter, Downey, Edgar, Edwards(Calif.), Fish, Frenzel, Hagedorn, Helstoski, Lent, Miller(Ohio), Mitchell(N.Y.), Moorhead(Pa.), Moss(Calif.), Pickle, Staggers, Stark, Ullman and Wilson(Tex.)

To authorize in the Energy Research and Development, and demonstration designed to promote electric vehicle technologies and to demonstrate the commercial feasibility of electric vehicles. (To Science and Technology.)

Status:

H.R. 6354 Research--automobile prototypes

By Corman

To establish a research and development program leading to advanced automobile prototypes. (To Science and Technology.)

Status:

H.R. 6531 Research--electric vehicles

By McCormack, Brown(Calif.), Teague, Mosher, Goldwater(Calif.), Andrews(N.D.) and Solarz

To authorize in the Energy Research and Development Administration a federal program of research, development, and demonstration designed to promote electric vehicle technologies and to demonstrate the commercial feasibility of electric vehicles. (To Science and Technology.)

Status:

H.R. 7117

By Scharp, Brodhead, Aekhardt, Moffett and Wirth

To require automobile manufacturers to meet mandatory fuel economy standards. (To Interstate and Foreign Commerce.)

Status:

## Coal and Mining

### H.R. 3217 Mining--coal--conversion

By Duncan(Tenn.)

To amend the Internal Revenue Code to encourage development of processes to convert coal to low-pollutant synthetic fuels. (To Ways and Means.)  
Status:

### H.R. 3333 Safety--occupational--coal mining

By Perkins

To amend the Federal Coal Mine Health and Safety Act of 1969. (To Education and Labor.)  
Status:

### H.R. 3414 Income tax deductions--moving expenses

By Duncan(Tenn.)

To amend the tax treatment of moving expenses. (To Ways and Means.)  
Status:

### H.R. 3439 Mining

By Johnson(Colo.)

To provide that moneys due the states under the provisions of the Mineral Leasing Act of 1920, as amended, may be used for purposes other than public roads and schools. (To Interior and Insular Affairs.)  
Status:

H.R.

### H.R. 3463 Mining--strip--regulation

By Moorhead(Pa.)

To provide for the cooperation between the Secretary of the Interior and the states with respect to the regulation of surface coal mining operations, and the acquisition and reclamation of abandoned mines. (To Interior and Insular Affairs.)  
Status:

### H.R. 3836 Research--coal--universities

By Derwinski

To establish university coal research laboratories and to establish energy resource fellowships. (To Science and Technology.)

## Oil and Natural Gas

### S. 745 Antitrust--competitive practices--petroleum industry

By Nelson, Abourezk, McIntyre, Clark, Hathaway, Packwood and Leahy

To amend the Interstate Commerce Act and to provide for regulation of certain anticompetitive developments in the petroleum industry. (To Judiciary.)

Status:

### S. 768 Energy--allocations--exemption

By Sparkman

To exempt small independent oil products from the Emergency Petroleum Allocation Act of 1973. (To Interior and Insular Affairs.)  
Status:

### S. 861 Energy--allocations--petroleum products

By Church, Johnston, Fannin, Hansen(Wyo.), Sparkman, Gravel, Cranston, Tunney, Humphrey, Curtis, McGee, Bayh, Abourezk, Buckley, Montoya,

Moss(Utah), Baker, Eastland, Hatfield, McClure, Bentsen and Tower

To amend Section 4 of the Emergency Petroleum Allocation Act of 1973. (To Interior and Insular Affairs.)  
Status:

### S. 922 Energy--allocations--natural gas

By Montoya

To amend the Natural Gas Act in order to give the Federal Power Commission emergency authority to allocate supplies of natural gas for agricultural purposes. (To Commerce.)  
Status:

### S. 973 Income tax--incentives--fuel use

By Bentsen

To amend the Internal Revenue Code of 1954 to provide incentives for the efficient use of gasoline and the increased use of coal and to encourage the development of synthetic fuels and solar energy. (To Finance.)  
Status:

### S. 1113 Public lands--petroleum reserves--establishment.

By Hatfield

To authorize the Secretary of the Interior to establish, on certain public lands of the United States, national petroleum reserves, the development of which needs to be regulated in a manner consistent with the total energy needs of the nation. (To Armed Services, Interior and Insular Affairs, and Banking, Housing and Urban Affairs.)  
Status:

### S. 1138 Antitrust--competitive practices--petroleum industry

By Hatfield

To amend the Clayton Act to preserve competition in the oil and gas pipeline industries in the United States. (To Judiciary.)  
Status:

### S. 1139 Mining

By Hatfield

To amend the Act of February 25, 1920 (30 U.S.C. 226(b)), and the Outer Continental Shelf Lands Act (43 U.S.C. 1337). (To Interior and Insular Affairs.)  
Status:

### S. 1182 Mining--oil and gas--leasing

By Roth

To amend certain provisions of law relating to the leasing of oil and gas deposits of the United States. (To Interior and Insular Affairs.)  
Status:

### S. 1186 States and municipalities--costal states--continental shelf development

By Hathaway

To amend the Outer Continental Shelf Lands Act in order to conduct a comprehensive study of the Outer Continental Shelf, to promote the development of Outer Continental Shelf oil and gas resources, to provide for protection of the environment, to promote competition in the production of oil and gas from the Outer Continental Shelf, to authorize

S. 1383 Mining--oil and gas--coastal zones  
By Bentsen

To amend the Outer Continental Shelf Lands Act with respect to payments to be made under oil and gas leases pursuant to such Act. (To Interior and Insular Affairs.)

Status:

S. 1405 Energy--allocations--gasoline  
By Weicker

To provide for the rationing of gasoline, to restrict imports of crude oil, to provide for the conservation of energy. (To Banking, Housing and Urban Affairs, Finance, and Interior and Insular Affairs.)

Status:

S. 1524 Income tax deductions--depletion allowance--oil and gas wells

By Hathaway

To terminate percentage depletion for oil and gas wells. (To Finance.)

Status:

S. 1546 Armed forces--petroleum supply--allocation

By Jackson

To amend Title 10, United States Code, to prevent discrimination against the armed forces of the United States in the supply of petroleum products. (To Judiciary.)

Status:

S. 1595 Imports--license fees--oil

By Jackson and Fannin

To authorize the payment of oil import license fees collected for imports into Puerto Rico, and for imports into the Customs Territory of the United States from the U.S. Virgin Islands. (To Interior and Insular Affairs.)

Status:

H.R. 3273 Energy--domestic supplies

By Preyer, Ashley, Carter, Coughlin, Davis, Devine, Dodd, Goodling, Helstoski, Hubbard, Regula, Roe, Seiberling, Schneebeli, Treen and Yatron.

To give greater assurance that national and regional needs are satisfied in times of shortage of natural gas and petroleum and its products. (To Interstate and Foreign Commerce.)

Status:

H.R. 3322 Antitrust--petroleum industry--franchised dealers

By Litton, McCloskey, Rees, Schroeder, Addabbo, LaFalce, McCormack, Holtzman, Harrington, Ryan, Krebs, Lent; Wilson(Tex.), Ford(Tenn.), Anderson(Ill.), Spellman, Moorehead(Calif.), Abzug, Beard(R.I.), Gude, Gaydos, Mitchell(Md.), Burgener, Downey and Stokes.

To provide for protection of franchised dealers in petroleum products. (To Interstate and Foreign Commerce.)

Status:

H.R. 3323 Antitrust--petroleum industry--franchised dealers

By Litton, Steiger(Wis.), Roe, Roncalio, AuCoin, Evans(Ind.), McKinney, Murtha, Simon, Fascell, Hays(Ohio), Corman, Richmond, Thompson, Stark, Edwards(Calif.), Eilberg, Boggs, Studds, Hechler(W. Va.), Zeferetti, Sarbanes, Fraser, Ketchum and Coughlin.

To provide for protection of franchised dealers in petroleum products. (To Interstate and Foreign Commerce.)

Status:

H.R. 3324 Antitrust--petroleum industry--franchised dealers

By Litton, Blester, Peyser, Neal, Sarasin and Jeffords.

To provide for protection of franchised dealers in petroleum products. (To Interstate and Foreign Commerce.)

Status:

H.R. 3399 Antitrust--petroleum industry--franchised dealers

By Broomfield

To provide for protection of franchised dealers in petroleum products. (To Interstate and Foreign Commerce.)

Status:

H.R. 3481 States and municipalities--coastal states--shelf lands development

By Roe

To amend the Coastal Zone Management Act of 1972 to authorize financial assistance to coastal states to enable them to study, assess, and plan the effects of offshore energy-related facilities and activities in or on the Outer Continental Shelf on their coastal zones, and to provide for needed public facilities and services; to provide assistance to the coastal states for coordinating coastal zone planning, policies, and programs in contiguous interstate areas. (To Merchant Marine and Fisheries)

Status:

H.R. 3594 Mining--oil shale--state share

By Johnson(Colo.)

To provide that moneys due the states under the provisions of the Mineral Leasing Act of 1920, as amended, derived from the development of oil shale resources, may be used for purposes other than public roads and schools. (To Interior and Insular Affairs.)

Status:

H.R. 3753 Energy--natural gas--deregulation

By Archer

To provide that certain provisions of the Natural Gas Act relating to rates and charges shall not apply to persons engaged in the production or gathering and sale but not in the transmission of natural gas. (To Interstate and Foreign Commerce.)

Status:

H.R. 3755 Energy--natural gas--agricultural uses

By Bauman

To establish priority allotments for natural gas used produce fertilizer and agricultural chemicals.

ORIGINAL PAGE IS  
OF POOR QUALITY

(To Interstate and Foreign Commerce.)  
Status:

H.R. 3808 Mining--oil and gas--outer continental shelf

By Studds

To establish a policy for the management of oil and natural gas in the Outer Continental Shelf; to protect the marine and coastal environment; to amend the Outer Continental Shelf Lands Act. (To Judiciary, Merchant Marine and Fisheries, Interior and Insular Affairs, and Science and Technology.)  
Status:

H.R. 3850 Imports--reduction--oil

By Gude

To amend the Emergency Petroleum Allocation Act of 1973 to reduce foreign oil imports and reliance on such imports by directing the President to equitably allocate gasoline and to recommend to the Congress an increase in the federal excise tax on gasoline purchases not subject to the program. (To Interstate and Foreign Commerce.)  
Status:

H.R. 3870 Energy--gasoline rationing--authority  
By McKinney

To amend the Emergency Petroleum Allocation Act of 1973 to direct the President to ration gasoline, to amend the Internal Revenue Code of 1954 to impose an energy conservation tax on gasoline. (To Interstate and Foreign Commerce, and Ways and Means.)  
Status:

H.R. 3876 Energy--prices--natural gas

By Moss, Abzug, Adams, Badillo, Brodhead, Brown (Calif.), Burke (Calif.), Carney, Corman, Dingell, Drinan, Eckhardt, Eilberg, Edwards (Calif.), Fascell, Ford (Tenn.), Harrington, Matsunaga, Ottinger, Rees, Richmond, Rooney, Scheuer and Sullivan.

To regulate commerce and amend the Natural Gas Act so as to provide increased supplies of natural gas, oil, and related products at reasonable prices to the consumer. (To Interstate and Foreign Commerce.)  
Status:

H.R. 3906 Energy--prices--oil

By Vanik, Abzug, Ambro, AuCoin, Badillo, Bennett, Boland, Brademas, Burke (Calif.), Conyers, Corman, Daniels (N.J.), Danielson, Duncan (Ore.), Edwards (Calif.), Fascell, Ford (Mich.), Ford (Tenn.), Fraser, Gilman, Gude, Harris, Hechler (W.Va.), Hicks and Hughes.

To amend the Emergency Petroleum Allocation Act of 1973 to prohibit the President from increasing the price of certain crude oil by more than \$1 per barrel per year. (To Interstate and Foreign Commerce.)  
Status:

H.R. 3981 See Environment

H.R. 4059 Energy--allocations--gasoline

By Adams

To amend the Emergency Petroleum Allocation Act of 1973 to establish a program for the creation and distribution of gasoline entitlements. (To Interstate and Foreign Commerce.)  
Status:

H.R. 4061 Income tax credits--foreign taxes--oil and gas wells

By Daniels (N.J.)

To amend the Internal Revenue Code of 1954 to deny percentage depletion in the case of foreign oil and gas wells to deny the deduction for intangible drilling and development costs in the case of such wells and to deny the foreign tax credit for taxes paid to foreign countries which are attributable to foreign oil related income. (To Ways and Means.)  
Status:

H.R. 4112 Mining--oil and gas--coastal zones

By Yates

To establish policy for the management of oil and natural gas in the Outer Continental Shelf; to protect the marine and coastal environment; to amend the Outer Continental Shelf Lands Act. (To Judiciary, Merchant Marine and Fisheries, Interior and Insular Affairs, and Science and Technology.)  
Status:

H.R. 4274 Natural resources--natural gas--priority use

By Andrews (N.D.), Davis, Stuckey and Evans (Colo.)

To provide priority system for certain agricultural uses of natural gas. (To Interstate and Foreign Commerce.)  
Status:

H.R. 4282 Imports--petroleum--government purchase  
By Cotter

To provide that all petroleum imported into the United States after September 1, 1975, shall not be available for purchase other than by the Government of the United States. (To Ways and Means, and Interstate and Foreign Commerce.)  
Status:

H.R. 4301 See Environment

4307 Ecology--recycled materials--oil

By Helstoski

To direct the Director of the National Bureau of Standards to issue regulations with respect to recycled oil. (To Science and Technology, and Ways and Means.)  
Status:

H.R. 4321 Energy--shortage--natural gas

By Freyer, McKinney and Mitchell (N.Y.)

To give greater assurance that national and regional needs are satisfied in times of shortage of natural gas and petroleum and its products. (To Interstate and Foreign Commerce.)  
Status:



H. R. 4442 Energy--allocations--exemption  
By Pickle, Boggs, Anderson(Calif.), Waggoner,  
Treen, Wright, Long(La.), Van Deerlin, Waxman and  
Krueger.

To amend the Emergency Petroleum Allocation Act  
of 1973 (Public Law 93-159) to exempt the first  
sale of the share of a state or local government  
or a subdivision thereof in crude oil produced in  
the United States from the mineral or leasehold  
estate-of any state or local government or subdivi-  
sion owned lands. (To Interstate and Foreign Com-  
merce.)

Status:

H.R. 4483 Energy--natural gas--agricultural uses  
By Andrews(M.D.), Davis, Stuckey, Evans(Colo.),  
and Bergland.

To provide priority system for certain agri-  
cultural uses of natural gas. (To Interstate and  
Foreign Commerce.)

Status:

H.R. 4488 Energy--allocation--exemption  
By Boggs, Pickle, Breaux, Herbert, Burleson(Tex.),  
Lujan, Patman, Young(Tex.), Collins(Tex.), Wilson  
(Tex.), Milford, Moore, Kazen, Brooks, Archer,  
Mahon, Roberts, Steelman, Casey, Mannaford,  
Passman and Wilson(C.H.-Calif.)

To amend the Emergency Petroleum Allocation Act  
of 1973 (Public Law 93-159) to exempt the first  
sale of the share of a state or local government or  
a subdivision thereof in crude oil produced in the  
United States from the mineral or leasehold estate  
of any state or local government or subdivision  
owned lands. (To Interstate and Foreign Commerce.)  
Status:

H.R. 4518 See Environment

H.R. 4554 Energy--allocations--petroleum products  
By Rousselot

To repeal the Emergency Petroleum Allocation Act  
(To Interstate and Foreign Commerce.)  
Status:

H.R. 4907 Antitrust--competitive practices--  
petroleum industry  
By Hechler(W.Va.)

To amend the Clayton Act to preserve and promote  
competition among corporations in the production of  
oil, natural gas, coal, oil shale, tar sands, ura-  
nium, geothermal steam, and solar energy. (To  
Judiciary.)

Status:

H.R. 4910 Antitrust--competitive practices--  
petroleum industry  
By Hechler(W.Va.)

To amend the Clayton Act to provide for ad-  
ditional regulation of certain anticompetitive  
developments in the petroleum industry. (To  
Judiciary, and Interstate and Foreign Commerce.)  
Status:

H.R. 4958 Severance taxes--distribution--energy  
sources  
By Perkins

To impose a tax on the severance of oil, gas,

and coal, and to return the proceeds of such tax  
to the counties from which such oil, gas, or coal  
was taken. (To Ways and Means.)

Status:

H.R. 5043 States and municipalities--coastal  
states--continental shelf development  
By Downey

To establish a policy for the management of oil  
and natural gas in the Outer Continental Shelf; to  
protect the marine and coastal environment; to  
amend the Outer Continental Shelf Lands Act. (To  
Judiciary, Merchant Marine and Fisheries, Interior  
and Insular Affairs, and Science and Technology.)  
Status:

H.R. 5173 Public lands--petroleum reserves--  
establishment

By Melcher, Johnson(Calif.), Steiger(Ariz.), Udall,  
Skubitz, Clausen(Don H.-Calif.), Byron, Young  
(Alaska), Santini, Johnson(Colo.), Tsongas,  
Risenhoover, Patman, Bell, Taylor(N.C.), Ruppe,  
Kastenmeier, Lujan, Mink, Sebelius, Meeds,  
Steelman, Bingham and Ketchum.

To authorize the Secretary of the Interior to  
establish on certain public lands of the U.S.  
national petroleum reserves the development of  
which needs to be regulated in a manner consistent  
with the total energy needs of the nation. (To  
Interior and Insular Affairs.)

Status:

H.R. 5279 Energy--allocations--petroleum products  
By Vanik and Leggett

To amend the Emergency Petroleum Allocation Act  
of 1973 to prohibit the President from increasing  
the price of certain crude oil by more than \$1 per  
barrel per year. (To Interstate and Foreign Com-  
merce.)

Status:

H.R. 5505 House of Representatives committees--  
select, establishment--natural gas and petroleum  
reserves

By Ashley

To create a select committee to make investi-  
gations and studies relating to natural gas and  
petroleum reserves. (To Rules.)

Status:

H.R. 5510 Imports--license fees--oil

By deLugo

To authorize the payment of oil import license  
fees collected for imports into Puerto Rico, and  
for imports into the Customs Territory of the  
United States from the U.S. Virgin Islands. (To  
Appropriations.)

Status:

H.R. 5663 Antitrust--petroleum industry--franchis-  
ed dealers

By Sisk

To provide for the protection of franchised dis-  
tributors and retailers of motor fuel. (To Inter-  
state and Foreign Commerce.)

Status:

ORIGINAL PAGE IS  
OF POOR QUALITY

H.R. 5670 Government contracts--petroleum--foreign supply  
By Fascell

To provide for the review of petroleum import supply contracts and to provide for authority for the government to enter into foreign supply contracts and to provide for authority for the government to enter into foreign supply contracts for petroleum. (To Ways and Means and Interstate and Foreign Commerce.)  
Status:

H.R. 5746 Government contracts  
By Harris

To provide that oil and gas from federal lands, including the Outer Continental Shelf, shall be produced by private persons under contract with the United States and marketed by the United States. (To Interior and Insular Affairs and Rules.)  
Status:

H.R. 5870 Energy--allocations--regulations  
By Drinan, Baucus, Bedell, Bingham, Brown(Calif.), Cornell, Cotter, Downey, Edwards(Calif.), Ford (Tenn.), Gude, Hawkins, Hechler(W.Va.) and Helstoski.

To require the President to take all necessary action to strictly enforce the regulation promulgated under Section 4 of the Emergency Petroleum Allocation Act of 1973 and all orders issued under such Act. (To Interstate and Foreign Commerce.)  
Status:

H.R. 5871 Energy--allocations--regulations  
By Drinan, Hicks, Holtzman, Maguire, Mitchell(Md.), Moakley, Ottinger, Richmond, Roe, Roybal, Solarz, Spellman, Stark, Thompson and Tsongas

To require the President to take all necessary action to strictly enforce the regulation promulgated under section 4 of the Emergency Petroleum Allocation Act of 1973 and all orders issued under such act..(To Interstate and Foreign Commerce.)  
Status:

H.R. 6068 Justice Department--special office--natural gas  
By McDade

To establish a special office in the Department of Justice to represent industrial end users of natural gas in any proceeding before the Federal Power Commission with respect to the curtailment of natural gas supplies. (To Judiciary.)  
Status:

H.R. 6127 Energy--prices--oil  
By Young(Fla.), and Tsongas

To amend the Emergency Petroleum Allocation Act of 1973 to provide for the equalization of residual fuel oil prices charged to public,private, and invested-owned utilities and other persons using such oil. (To Interstate and Foreign Commerce.)  
Status:

H.R. 6310 Energy--price--oil  
By Emery

To amend the Internal Revenue Code to encourage the continuation of family farms. (To Ways and Means).  
Status:

H.R. 6377 Ecology--recycled materials--oil  
By Vanik, Bedell, Carr, Evans(Ind.), Ellberg, Fithian, Hannaford, Jeffords, Rangel, Seiberling, Solarz and Stokes.

To provide for the recycling of used oil. (To Interstate and Foreign Commerce, Ways and Means, Government Operations, and Science and Technology.)  
Status:

H.R. 6385 Antitrust--petroleum industry--Franchised dealers  
By Downey

To regulate commerce and to protect petroleum product dealers from unfair practices. (To Interstate and Foreign Commerce.)  
Status:

H.R. 6520 Consumer protection--disclosure--gasoline  
By Dingell and Conte

To require that certain information about automotive gasoline octane be disclosed to consumers. (To Interstate and Foreign Commerce.)  
Status:

H.R. 6557 Energy--prices  
By Eilberg

To amend the Federal Energy Administration Act of 1974 in order to provide for the prohibition of certain discriminatory practices in the pricing of fuels and other forms of energy, including electricity. (To Interstate and Foreign Commerce.)  
Status:

H.R. 6598 Energy--Research and Development Administration--synthetic fuels production  
By Perkins

To provide for acquisition and construction by the Energy Research and Development Administrator of facilities for the production of synthetic fuels from coal and oil shale, for lease of such facilities to private enterprise for operation and marketing of output, and for sale or other disposition of such facilities to private enterprise with certain disposition of such facilities to private enterprise with certain options for such leases. (To Interior and Insular Affairs.)  
Status:

H.R. 6927 See Transportation

H.R. 7078 Energy--prices--regulation  
By Brown(Ohio)

To amend the Emergency Petroleum Allocation Act of 1973 by adding at the end thereof a new Section with respect to crude oil price regulation. (To Interstate and Foreign Commerce, and Ways and Means.)  
Status:

H.R. 7116 Income tax credits--exploration and development--oil  
By Archer

To provide a tax credit for expenditures made in the exploration and development of new reserves of oil and gas in the United States. (To Ways and Means.)  
Status:

### Solar Geothermal, Atomic and Energy from Solid Waste

S. 994 Authorizations--supplemental 1975--  
Nuclear Regulatory Commission  
By Pastore

To authorize supplemental appropriations to the Nuclear Regulatory Commission for fiscal year 1975. (To Atomic Energy.)  
Status:

S. 1199 Atomic energy--uranium tailings--Utah  
By Moss(Utah)

To authorize the Energy Research and Development Administration to enter into a cooperative agreement with the State of Utah to remove and dispose of uranium mill tailings. (To Atomic Energy.)  
Status:

S. 1379 Income tax credits--solar energy equipment  
By Fannin

To amend the Internal Revenue Code of 1954 to provide for tax credits for certain applications of solar energy equipment. (To Finance.)  
Status:

S. 1474 Solid waste disposal--resource recovery  
By Domenici and Stafford

To amend the Solid Waste Disposal Act to authorize state program and implementation grants, to encourage full recovery of energy and resources from solid waste, to reduce waste, to control the disposal of hazardous wastes. (To Public Works.)  
Status:

S. 1716 Authorizations  
By Pastore and Baker

To authorize appropriations to the Nuclear Regulatory Commission in accordance with Section 261 of the Atomic Energy Act of 1954, as amended, and Section 305 of the Energy Reorganization Act of 1974. (To Appropriations.)  
Status:

S. 1717 Atomic energy--production sites  
By Pastore and Baker

To amend the Atomic Energy Act of 1954, as amended, to provide for approval of sites for production and utilization facilities. (To Atomic Energy.)  
Status:

H.R. 3274 Authorizations--fiscal 1975--Nuclear Regulatory Commission  
By Price

To authorize appropriations to the Nuclear Regulatory Commission in accordance with Section

261 of the Atomic Energy Act of 1954, as amended, and Section 305 of the Energy Reorganization Act of 1974. (To Atomic Energy.)  
Status:

H.R. 3275 Authorizations--supplemental 1975--  
Nuclear Regulatory Commission  
By Price

To authorize supplemental appropriations to the Nuclear Regulatory Commission for fiscal year 1975. (To Atomic Energy.)  
Status:

H.R. 3809 Atomic energy--nuclear power facilities  
By Thornton

To create a National Power Resources Authority for the development of nuclear power facilities. (To Atomic Energy.)  
Status:

H.R. 3849 Housing--low interest loan program--  
insulation and heating equipment  
By Gude

To establish in the Department of Housing and Urban Development a direct low-interest loan program to assist homeowners and builders in purchasing and installing solar heating (or combined solar heating and cooling) equipment. (To Banking, Currency and Housing.)  
Status:

H.R. 3909 Noise abatement--aircraft--sonic booms  
By Wolff, Burke(Calif.), Roybal, Yates, Mitchell (Md.), Harrington, Tsongas, Studds, Abzug, Addabbo, Badillo, Holtzman, Koch, Pattison, Rangel, Scheuer, Solarz, Seiberling, Eilberg and Ford(Tenn.)

To prohibit commercial flights by supersonic aircraft into or over the United States until certain findings are made by the Administrator of the Environmental Protection Agency and by the Secretary of Transportation. (To Public Works and Transportation.)  
Status:

H.R. 4619 Housing--low interest loan program--  
insulation and heating equipment

By Gude, Downing, Downey, Helstoski, Giaimo, Drinan, Edgar, Coughlin, Anderson(Calif.), Fascell, Stark, Eilberg, Bedell, Richmond, Sarbanes, Yates and Harris.

To establish in the Department of Housing and Urban Development a direct low-interest loan program to assist homeowners and builders in purchasing and installing solar heating (or combined solar heating and cooling) equipment. (To Banking, Currency and Housing.)  
Status:

H.R. 4945 Atomic energy--licensing--plutonium  
By Aspin, Abzug, Badillo, Edgar, Edwards(Calif.), Fascell, Fish, Hannaford, Harrington, Hawkins, Hechler(W.Va.), Holtzman, Hubbard, Koch, Moakley, Moorhead(Pa.), Mottl, Neal, Ottinger and Pattison.

To prohibit the licensing of certain activities regarding plutonium until expressly authorized by Congress, and to provide for a comprehensive study of plutonium recycling. (To Atomic Energy.)  
Status:

H.R. 4946 Same as H.R. 4945

H.R. 4971 Atomic energy--nuclear power plants--  
construction licenses  
By Fish and Pattison

To terminate the granting of construction licenses of nuclear fission powerplants in the United States pending action by the Congress following a comprehensive five-year study of the nuclear fuel cycle, with particular reference to its safety and environmental hazards, to be conducted by the Office of Technology Assessment. (To Atomic Energy)  
Status:

H.R. 5406 Atomic energy--nuclear fuel cycle study  
By Drinan

To provide for a comprehensive five-year study of nuclear fuel cycle, with particular reference to its safety and environmental hazards, to be conducted by the Office of Technological Assessment. (To Atomic Energy.)  
Status:

H.R. 5460 Housing--low interest loan program--  
insulation and heating equipment  
By Gude, Mitchell(Md.), Fenwick, Mann, Jenrette,  
Stokes, Hecker(Mass.), Blanchard, Hannaford,  
Cleveland and Wirth.

To establish in the Department of Housing and Urban Development a direct low-interest loan program to assist homeowners and builders in purchasing and installing solar heating (or combined solar heating and cooling) equipment. (To Banking, Currency and Housing.)  
Status:

H.R. 5698 Atomic energy  
By Lloyd(Tenn.), Quillen, Duncan(Tenn.), Evins  
(Tenn.), Fulton, Beard(Tenn.), Jones(Tenn.) and  
Ford(Tenn.)

To amend the Atomic Energy Community Act of 1955 to authorize the Administrator of the Energy research and Development Administration to make assistance payments to Anderson County and Roane County, Tennessee. (To Atomic Energy.)  
Status:

H.R. 5833 Research--magnetohydrodynamics  
By Baucus, Bedell, Carney, Carr, Cornell, Coughlin,  
Daniels(N.J.), Frenzel, Harrington, Hawkins, Ichord,  
Krebs, Neal, Pepper, Roybal, Spellman, Studds,  
Tsongas, Weaver, Wilson(Texas), Winn and Yatron.

To authorize a vigorous federal program of research, development, and demonstration to assure the utilization of MHD(Magnetohydrodynamics) to assist in meeting our national energy needs. (To Science and Technology.)  
Status:

H.R. 5959 Income tax credits--residential improvements--insulation  
By Wylie

To amend the Internal Revenue Code of 1954 to provide a tax credit for expenditures by a taxpayer for solar heating and cooling equipment installed in new or existing buildings, and a tax credit for expenditures by an individual for insulation in such individual's principal residence. (To Ways & Means.)

H.R. 6329 See Environment

H.R. 6394 Atomic energy--licensing--plutonium  
By Aspin, Bedell, Bingham, Burke(Calif.), Carr,  
Carter, Daniels(N.J.), Fenwick, Fraser, Hall,  
Harkin, Heckler(Mass.), Metcalfe(Ill.), Moakley,  
Moffett, Richmond, Rodino, Roe, Rose and Rosenthal.

To prohibit the licensing of certain activities regarding plutonium until expressly authorized by Congress, and to provide for a comprehensive study of plutonium recycling. (To Atomic Energy.)  
Status:

H.R. 6584 Income tax credits--investment credits--  
insulation  
By Gude

To amend the Internal Revenue Code of 1954 to allow a taxpayer to amortize over a 60-month period, solar heating and cooling equipment, which is placed in service for nonresidential structures, or in lieu of such amortization, to take an investment tax credit for such equipment. (To Ways and Means.)  
Status:

H.R. 6870 Atomic energy--nuclear power plants--  
construction licenses  
By Fish, Abzug, Bedell, Blouin, Bonker, Chisholm,  
Dellums, Edgar, Fenwick, Harkin, Hechler(W.Va.),  
Mezvinsky, Mitchell(Md.), Moakley, Moffett, Mottl,  
Pattison, Rodino, Rosenthal, Roybal, Seiberling  
and Weaver,

To terminate the granting of construction licenses of nuclear fission powerplants in the United States pending action by the Congress following a comprehensive five-year study of the nuclear fuel cycle, with particular reference to its safety and environmental hazards, to be conducted by the Office of Technology Assessment. (To Atomic Energy.)  
Status:

H.R. 7001 Authorizations  
By Price

To authorize appropriations to the Nuclear Regulatory Commission in accordance with Section 261 of the Atomic Energy Act of 1954, as amended, and Section 305 of the Energy Reorganization Act of 1974. (To Atomic Energy.)  
Status:

H.R. 7002 Atomic energy--production sites  
By Price

To amend the Atomic Energy Act of 1954, as amended, to provide for approval of sites for production and utilization facilities. (To Atomic Energy.)  
Status:

H.R. 7130 Housing--low income--energy conversion  
improvements  
By Gude and Fithian

To establish in the Department of Housing and Urban Development a direct low-interest loan program to assist homeowners and builders in purchasing and installing solar heating (or combined solar heating and cooling) equipment. (To Banking, Currency and Housing.)  
Status:

Other

S. 744 Research--magnetohydrodynamics  
By Mansfield and Metcalf(Mont.)

To authorize a vigorous federal program of research, development, and demonstration to assure the utilization of MHD (magnetohydrodynamics) to assist in meeting our national energy needs. (To Interior and Insular Affairs.)

Status:

S. 808 Housing--low income--fuel stamps  
By Hartke and Humphrey

To establish an emergency fuel stamp program to assist low-income households to meet the rising cost of fuel used in home heating and cooking. (To Labor and Public Welfare.)

Status:

S. 897 Income tax--incentives--energy conservation  
By Mathias(Md.)

To amend the Internal Revenue Code of 1954 to provide incentives for energy conservation. (To Finance.)

Status:

S. 911 Public buildings--energy conservation--design  
By Pell

To encourage the conservation of energy by requiring that certain buildings financed with federal funds are so designed and constructed that the windows in such buildings can be opened and closed manually. (To Banking, Housing and Urban Affairs.)

Status:

S. 984 States and municipalities--land resources development programs

By Jackson, Abourezk, Brooke, Bumpers, Church, Cranston, Gravel, Hart(Mich.), Hart(Colo.), Haskell, Hatfield, Hollings, Humphrey, Inouye, Javits, Kennedy, McGee, Magnuson, Metcalf(Mont.), Mondale, Montoya, Nelson, Packwood, Randolph, Ribicoff, Stevenson, Tunney and Johnston.

To authorize the Secretary of the Interior to make grants to assist the states to develop and implement state land resource programs and to assist Indian tribes to plan the use of tribal lands; to encourage expeditious energy facility siting decisions; to coordinate federal programs which significantly affect land use; to encourage research on and training in land resource planning and management; to establish an Office of Land Resource Planning Assistance in the Department of the Interior. (To Interior and Insular Affairs.)

Status:

S. 1112 Energy--Energy Trust Fund  
By Gravel

To establish an Energy Trust Fund funded by a tax on energy sources, to provide for the development of domestic sources of energy and for the more efficient utilization of energy. (To Finance.)

Status:

S. 1149 Energy--conservation  
By Humphrey and Jackson

To provide for a national fuels and energy conservation policy, to establish a national energy conservation program. (To Interior and Insular Affairs, Banking, Housing and Urban Affairs, Commerce, Finance, Government Operations, and Public Works.)

Status:

S. 1207 Energy--Energy Production Corporation  
By Schweiker

To establish the Federal Energy Production corporation. (To Interior and Insular Affairs.)

Status:

S. 1208 Energy  
By Metcalf(Mont.), Mansfield, Humphrey, Moss(Utah), McGovern, Abourezk and Hathaway.

To improve the nation's energy resources. (To Commerce.)

Status:

S. 1392 Energy--conservation--demonstration program  
By Tunney

To establish a demonstration program in energy conservation, using promising innovative technology to the maximum extent possible, through retrofitting existing buildings with energy conservation equipment and systems. (To Public Works, Commerce and Government Operations.)

Status:

S. 1515 Excise taxes--gasoline--increase  
By Stafford

To amend the Internal Revenue Code of 1954 to encourage efficient energy use, to reduce United States dependence on foreign petroleum. (To Finance.)

Status:

S. 1742 Energy  
By Brooke and Metcalf(Mont.)

To amend the Federal Energy Administration Act of 1974 in order to provide for the prohibition of certain practices which encourage additional use of electricity and natural gas. (To Commerce.)

Status:

S. 1777 Ecology-- environmental protection--electrical power supply facilities  
By Randolph, Jackson and Magnuson.

To require that new and, to the extent practicable, existing electric powerplant boilers and major industrial boilers which utilize fossil fuels be capable of utilizing coal as their primary energy fuel in conformity with applicable environmental requirements. (To Interior and Insular Affairs and the Committee on Public Works.)

Status:

H.R. 3573 Housing--low and middle income--energy conservation improvements

By Barrett and Reuss.

To assist low and middle income owners of residential structures in purchasing and installing energy conservation improvements. (To Banking, Currency and Housing.)

ORIGINAL PAGE IS  
OF POOR QUALITY

H.R. 3750 Energy--Energy Conservation Corporation  
By McFall, Teague, Eshleman, Ashley, Badillo,  
Brademas, Brown(Calif.), Burke(Calif.), Carney,  
Corman, Cotter, Daniels(N.J.), Danielson, Drinan,  
Edwards(Calif.), Eiberg, Florio, Ford(Tenn.), Ford  
(Mich.), Hawkins, Helstoski, Hubbard and Hungate.

To establish a National Energy and Conservation  
Corporation (AM-POWER), and for other purposes. (To  
Interior and Insular Affairs and Science and Tech-  
nology.)

Status:

H.R. 3775 Public utilities

By Forsythe

To assure protection of environmental values  
while facilitating construction of needed electric  
power supply facilities. (To Interstate and Foreign  
Commerce.)

Status:

H.R. 3860 Energy--Energy and Conservation Corpo-  
ration

By Hammerschmidt

To establish a National Energy and Conservation  
Corporation (AM-POWER). (To Interior and Insular  
Affairs, and Science and Technology.)

Status:

H.R. 4071 Energy--allocations--exemption

By Heinz

To provide for more effective congressional re-  
view of administrative actions which exempt petro-  
leum products from the Emergency Petroleum Alloca-  
tions Act of 1973, or which result in a major in-  
crease in the price of domestic crude oil; and to  
provide for an interim extension of certain expir-  
ing energy authorities. (To Interstate and Foreign  
Commerce.)

Status:

H.R. 4434 Energy--Energy and Conservation Corpo-  
ration

By McFall, Teague, Udall and Bergland

To establish a National Energy and Conservation  
Corporation (AM-POWER). To Interior and Insular  
Affairs, and Science and Technology.)

Status:

H.R. 4658 Mining--oil and gas--offshore leasing

By Bell, Miller(Calif.), Ryan, Stark, Corman,  
Maguire, Abzug, Hawkins, Krebs, Hannaford, Roybal,  
Emery, Helstoski, Carney, Ambro, Cleveland, Rich-  
mond, Solarz and Holtzman.

To amend the Outer Continental Shelf Lands Act  
to provide a procedure for congressional disapproval  
of offshore oil and gas leases. (To Interior and  
Insular Affairs, and Rules.)

Status:

H.R. 4693 Energy--shortages--natural gas

By McDade

To give greater assurance that national and re-  
gional needs are satisfied in times of shortage of  
natural gas and petroleum and its products. (To  
Interstate and Foreign Commerce.)

Status:

H.R. 4728 Income tax credits--residential improve-  
ments--thermal design

By Vanik, Alexander and Wolff

To amend the Internal Revenue Code of 1954 to  
allow an income tax credit or an income tax deduc-  
tion for certain expenditures of a taxpayer relat-  
ing to the thermal design of the residence of such  
taxpayer. (To Ways and Means.)

Status:

H.R. 4799 Rural affairs

By Poage

To amend Sections 306 and 308 of the Rural  
Electrification Act of 1936, as amended. (To  
Agriculture.)

Status:

H.R. 4858 See Environment

H.R. 4862 Energy--Energy and Conservation Corpo-  
ration

By McFall, Teague and Hannaford.

To establish a National Energy and Conservation  
Corporation (AMPOWER). (To Interior and Insular Af-  
fairs, and Science and Technology.)

Status:

H.R. 4876 Housing--low and middle income--energy  
conservation improvements

By St. Germain

To assist low- and middle-income owners of resi-  
dential structures in purchasing and installing  
energy conservation improvements. (To Banking,  
Currency and Housing.)

Status:

H.R. 4907 Antitrust--competitive practices--  
petroleum industry

By Hechler(W.Va.)

To amend the Clayton Act to preserve and promote  
competition among corporations in the production of  
oil, natural gas, coal, oil shale, tar sands, ura-  
nium, geothermal steam, and solar energy. (To  
Judiciary.)

Status:

H.R. 5005 Energy--conservation

By Ullman

To provide a comprehensive national energy con-  
servation and conversion program. (To Ways and  
Means.)

Status:

H.R. 5027 Consumer protection--energy supplies

By Roybal, Burke(Calif.) and Drinan

To regulate commerce by assuring that adequate  
supplies of energy resource products will be avail-  
able at the lowest possible cost to the Consumer.  
(To Interstate and Foreign Commerce.)

Status:

H.R. 7080 Public buildings--energy conservation--  
design

By Cleveland and Howard.

To insure that certain buildings financed with  
federal funds utilize the best practicable tech-  
nology for the conservation and use of energy. (To  
Public Works and Transportation.)

## N.2 STATE ENERGY-RELATED LEGISLATION (as of June 1975)

\*Signed by the Governor

## 1. Utilities/Public Power

Colorado-H1666	Permits political subdivisions which own municipal electric systems to provide any service through the establishment of a separate entity to produce, generate, and transmit electric power and energy supplies.
Connecticut-S1081	Concerning the establishment of a public utilities control authority.
Connecticut-S311*	Concerning the establishment of municipal electric energy cooperatives.
Georgia-H31*	Creates the Georgia Municipal Electric Authority to acquire, construct,...public projects, embracing generation and transmission of electric power and energy.
Iowa-H908*	Make technical amendments to clarify that the powers to form joint electrical utilities are given to cities, rather than city utilities which are not municipal corporations.
Maine-H414(LD501)*	Act to authorize the plantation of Matinicus to establish an electric power generating authority.
Nebraska-L860*	Provide procedures for any city or village to contract for energy.
Nebraska-L862*	Provides that the exercise of powers of public power districts may be delegated.
Nebraska-L863*	Changes when sealed bids shall be required prior to entering into contracts.
Nebraska-L8104*	Provide powers to contract for the generation of electric power and energy.
Nevada-ACR38*	Directs the Legislative Commission to study electric utility companies, gas utility companies and the PSC of Nevada.
Nevada-A500	Creates an energy management division within the the PSC of Nevada.
Nevada-A275*	Creating a committee to study electric utility companies, gas utility companies and the Public Service Commission of Nevada
North Carolina-H266*	Authorizing municipalities in the State of North Carolina to jointly cooperate in the generation and transmission of electric power and energy and to jointly own and operate facilities therefor.
North Carolina-SJR343*	Urging the North Carolina Utilities Commission to conduct a fuel allocation policy study and to develop a long-term policy for the State.
Pennsylvania-SR8*	Investigate cause of power failures and reasons for high cost of electricity.
Rhode Island-S651*	Regulating the ownership of electric generating facilities.

Rhode Island-HR5920*	Resolution to study the feasibility of the State of Rhode Island developing and owning any and all new electric generating facilities within the State.
South Dakota-H764*	Legalize and validate certain expenditures, acquisitions and contracts made by and entered into by consumers power districts.
South Dakota-H767*	Relating to contractual powers of a consumers power district.
Tennessee-S764*	Permits municipalities to build and operate energy reduction and delivery facilities.
Utah-H111*	Authorize joint participation between Utah cities, public service companies in planning, financing, construction, acquisition, ownership, operation and maintenance of thermal power facilities.
Utah-S87*	Adding electrical facilities to items for which municipalities may issue bonds.

---

#### Utilities/Rate Structure

Connecticut-S1595*	Concerns state payment of utility bill interest charges.
Maine-S469(LD1603)*	Prohibit the arbitrary imposition of certain fuel charges by electric power utilities.
Maine-LD1663*	Requires the PUC to consider the efficiency with which a utility operates in granting rate increases.
Maryland-H48 (Vetoed)	Requiring the Public Service Commission to study certain rate structures used by gas and electric companies under its jurisdiction and investigate alternatives.
Michigan-HR17*	Creating a special committee to study the various factors which determine the rate structure of public utilities.
North Carolina-H506*	Authorizes the Utilities Commission to establish rules for filing rate cases.
North Carolina-H368*	Provides for the fixing of utility rates in N.C. based upon the reasonable original cost of the property used and useful in providing service to the public.
North Carolina-S133*	Enlarges the North Carolina Utilities Commission; requires separate hearing on rate increases based solely upon fuel costs.
North Dakota-HCR3088*	Directs the Legislative Council to conduct a study of the Public Service Commission's authority to establish electrical rates.

---

#### Utilities/Consumer Advocacy

Connecticut-H7491	An act concerning the termination of service by Public Service Companies.
Connecticut-H7623	An act concerning advertising by gas and electric public service companies.
Delaware-S241*	Exempts the gross receipts and tariff charges received by electricity, gas and telegraph companies from residential consumers and users and the sale price or tariff charges paid by residential consumers to the telephone company from the public utility tax.



Delaware-SCR28*	Directs the Public Service Commission to adopt regulations requiring utility companies of this state to institute and publish a customer bill of rights establishing certain procedures for resolving customer complaints.
Delaware H222*	Substantially revises business license, occupation licenses, and the mercantile tax. Adds a gross receipts charge in addition to occupational licenses, required of all retailing goods and services.
Georgia-H473*	Provides that no gas or electric utility company shall cut off service because resident has failed to pay for any appliance purchased from such company.
Indiana-S535*	Relates to the power of the Public Service Commission to change rate schedules without hearing procedures.
Maryland-H685 (Vetoed)	Providing electric bill savings to the citizens of certain counties while maintaining air quality at levels fully adequate to protect the public health and preserve the environment.
West Virginia-H966 (Veto Overridden)	Requiring the commission to hold a full public hearing before allowing a public utility to increase price charged for electricity due to certain increased fuel costs.

ORIGINAL PAGE IS  
OF POOR QUALITY

#### Tax Exemptions/Motor Fuel

Georgia-H617*	Provides that sale of motor fuel to an ultimate consumer who has both high and nonhighway uses shall not be subject motor fuel tax.
Georgia-H315*	Relates to exemptions for motor fuel other than gasoline used for nonhighway purposes.
Montana-H53*	Relates to the school transportation reimbursement rate schedules, providing an increase of the bus per mile reimbursement.
South Dakota-S287(Vetoed)	Relating to exemption of motor fuel used for agricultural purposes from taxation.

#### Tax Exemptions/Heating Fuel

Vermont-S54*	Exempt electricity used in residences and heating fuels used in residences from the sales and use tax.
--------------	--

#### Tax Exemptions/Building Efficiency

Montana-H663*	Encourages investment in nonfossil forms of energy generation and in energy conservation in buildings through tax incentives and capital availability.
---------------	--

#### Tax Exemptions/Incentives/Solar Heating and Cooling

Arizona-S1011*	Amendments to the act providing for tax deductions for installing solar energy devices.
Colorado-S75*	Concerns the valuation for assessment of solar heating and cooling devices.
Maryland-H1604*	Requiring that solar energy heating and cooling units used in certain buildings be assessed in a manner so as to not exceed the assessment of conventional heating and cooling units.
Montana-H663*	Encourages investment in nonfossil forms of energy generation and in energy conservation in buildings through tax incentives and capital availability.
New Mexico-S1*	Providing for a credit against personal income tax due to the conversion to or construction of solar energy systems; providing for a refund to taxpayers, if credit allowed exceeds tax liability.
North Dakota-S2439*	Exemption from property taxes and sales and use taxes of solar energy systems to heat or cool buildings and structures.

Tax Exemptions/Incentives/Solar Heating and Cooling

Oregon-H2202	Provides tax exemption on increased value of property as a result of solar energy heating and cooling systems.
South Dakota-S283*	Provides for a property tax deduction for the utilization of solar energy systems.

---

Tax Exemptions/Utility Sales

South Dakota-S32*	Act relating to the exemption of fuel used by utilities and industry from the use tax is repealed.
-------------------	--

---

Tax Applications/Depletion

California-A177*	Limits the total accumulated amount of depletion that would be taken to an amount equal to the adjusted cost of a taxpayer's interest in such oil or gas wells which is subject to recovery through the application of the depletion allowance.
Delaware-H137*	Disallows deductions for percentage depletion of oil and gas wells in computing taxable income.

---

Tax Applications/Motor Fuel

Colorado-S27	Deletes requirement for an annual permit to use special fules; allows permit to remain in effect until the vehicle is sold or the owner fails to file a report to pay the special fuel tax.
Delaware-H130*	Relating to the motor fuel tax by increasing the tax on special fuel.
Minnesota-H1722*	Increases the excise tax on gasoline and gasoline substitutes.
Montana-H295*	Imposes a license tax in lieu of a fuel tax on each and every vehicle self-propelled upon the public highways and streets of this State using liquid petroleum gases.
South Dakota-H567*	Relating to the imposition of the tax upon motor fuels, and providing for a municipal motor fuel tax fund.
Maine-H131(LD161)*	Makes clear that interest applies when a report is filed by a gasoline distributor without payment as well as when no report is filed.

---

Franchiser Protection/Retailer Prerequisites

Arkansas-S38*	Clarify the contractual relationship between petroleum products suppliers or petroleum products distributors and petroleum products dealers as defined herein.
Maine-H124(LD160)*	Relating to use fuel tax audits.
Maine-H131(LD161)*	Makes clear that interest applies when a report is filed by a gasoline distributor without payment, as well as when no report is filed.
Minnesota-H486*	Term "Franchise" includes agreements under which the franchisee may market motor vehicles and motor vehicle fuel.
Hawaii-S1699*	Concerning the procurement, control, distribution and sale of petroleum products.
Maine-H735(LD920)*	Regulates the distribution and sale of motor fuels.
Vermont-S19*	Gives service station operators certain rights when dealing with the oil companies supplying them with products.

---

Conservation/Energy Price Labeling

Connecticut-H7617                      Concerning posting of gasoline signs.

Conservation/Appliance Labeling

California-S213                      No person shall be sold any new gas appliance without containing a seal of certification.

Conservation/Building Efficiency Standards

California-S119\*                      Relates to energy conservation standards for nonresidential buildings.

Minnesota-H923\*                      Postponing the deadline for promulgation of energy conserving building design and construction standards by the commissioner of administration from April 1, 1975 to July 1, 1975.

New Mexico-H395\*                      Providing that a feasibility study of the energy source for heating and air conditioning must be made before any contract is executed for the construction or major alteration of a state building.

Nevada-A716\*                      Requires adoption of minimum insulation standards for all public and private buildings constructed in Nevada.

North Carolina-S151\*                      Requires state agencies to make energy consumption analyses of major construction or renovation of buildings.

North Carolina-SR149\*                      Conservation of energy through the North Carolina Building Code.

North Carolina-SR150\*                      Energy conservation through "Energy Consumption Analysis" of government buildings, including schools.

Oregon-S283                      To provide maximum energy conservation in design, construction and repair of buildings.

Texas-S516\*                      Relates to energy conservation in certain buildings.

Conservation/Appliance Efficiency Standards/Industrial

North Carolina-S420\*                      Establishes an expansion policy for electric utility plants in N.C. to promote greater efficiency in the use of all existing plants, and to reduce electricity costs by requiring greater conservation of electricity.

Research and Development

Iowa-S289\*                      Appropriation of monies to a research (energy) and development fund.

Montana-S86\*                      Creating a fund for research, development and demonstration of alternative energy sources and allocating certain revenue from coal taxes to the fund.

New Mexico-S185\*                      Relating to energy research and development; creating the energy research and development Review Committee.

Resource Development/Nuclear

Arkansas-H659\*                      Establish within the Arkansas Department of Health a statewide radiation control financial responsibility program embracing licensee performance bonding and perpetual care trusts.

Connecticut-H7661                      An act concerning creation of a temporary nuclear power evaluation council.

Kansas-H2071\*                      Relating to the nuclear energy council.

Nevada-A761*	Designates health division of Department of Human Resources as State Radiation Control Agency.
Oregon-S55*	Permits health division to take emergency action to safeguard public against radiation sources; requires hearings in certain circumstances.
Oregon H2629	Permits the holder of a permit to construct a nuclear fueled thermal power plant to contract to make advance payments to local governments.
Oregon-HJR31*	Directs Nuclear and Thermal Energy Council to designate as unsuitable for thermal power plants in Newberry Crater, Lava Cast Forest and roadless areas.
Rhode Island-S806	Investigates the construction of coal-fired power plants as a viable alternative to the construction of nuclear power plants.
Rhode Island-H5219 (Vetoed)	Reserving to the general assembly exclusive jurisdiction over all plans for the location and construction of an oil refinery or a nuclear plant anywhere within the State.
Vermont-H127*	Provides for legislative review in the siting of nuclear power plants.
Virginia-H1694*	Relating to the definitions for radiation control and the powers and duties of the state department of health as the State Radiation Control Agency.

#### Resource Development/Facility Siting

Connecticut-S994	Concerning the Power Facility Evaluation Council.
Connecticut-H8262	Concerning the authority of the Power Facility Evaluation Council.
Connecticut-S18	Concerning regional referenda for oil refineries.
Georgia-SR123*	Creates the Power Plant Siting Study Committee.
Maryland-???	Establishes local government controls over the siting of coastal petroleum refineries.
Montana-H453*	Providing for the suspension of action on certain applications for certificates of environmental compatibility and public need for two years during which time a comprehensive Montana energy policy and plan shall be formulated.
Montana-H581*	Amends the Montana Utility Siting act of 1973.
North Dakota-S2050*	Provide for energy conversion facility and transmission facility siting authority by the Public Service Commission.
North Carolina-S549*	Establishes a Utility Review Committee.
Tennessee-S301*	Enacts the Energy Facility Siting Act of 1975.
Tennessee-S362*	Changes definition of "Energy Recovery Facility" to include recovery for use in production of electricity.
Wyoming-H125*	Relates to major industrial facilities siting.

#### Resource Development/Revenue

Arizona-HCM2004*	Urging New Mexico to reconsider its enactment of its "Electrical Energy Tax Act" and urging Congress to enact legislation prohibiting the imposition of such a tax by any State.
Colorado-S54*	Concerns the oil shale special fund; providing that interest earned by federal mineral leasing moneys from oil shale lands shall be expended for the same purposes as the original leasing moneys.

Delaware-H97 (Vetoed)	Relating to a tax on petroleum refineries.
Montana-S13*	Providing for a severance tax on coal produced at 25% of value.
Montana-S14*	Replacing the natural gas distributors' tax with a severance tax on the production of natural gas.
Nevada-A158	Relating to lease of state lands; increasing the royalty under oil, coal or gas leases.
New Mexico-S258*	Imposes a tax on the generation of electricity.
New Mexico-S186*	Creating the Energy Resources Commission; increasing the rate of oil and gas conservation tax and extending its application to all other forms of energy severed from the soil of New Mexico.

#### Resource Development/Renewable Resources

Arizona-S1018*	Establishing a solar energy research commission and a solar energy research council.
Colorado-S95	Concerns solar easements, and provides for the creating and conveyancing thereof.
Maine-S175(LD544)*	Protects tidal resources as a source of power generation.
Montana-S79*	Requiring the owners of oil and gas wells to file bottom-hole temperatures with the board of oil and gas conservation to facilitate the discovery of potential geothermal energy sources.
Nevada-S158	Relating to geothermal resources.
Nevada-SCR28*	Directs state engineer to appoint a committee to study government regulations pertaining to development, control and conservation of geothermal resources in Nevada.
New Mexico-S120*	Relating to solar energy resources.
New Mexico-H276*	Relating to the conservation, regulation and prevention of waste of geothermal resources, gives the oil conservation commission authority to regulate, conserve and prevent waste of geothermal resources.
Oregon-H2040	Requires Nuclear and Thermal Energy Council to act on an application for geothermal-fueled thermal power plant within 6 months of filing.
Oregon-H2036*	Adds solar energy consideration to comprehensive planning.
Oregon-H3185	Authorizes formation of geothermal heating districts; authorizes districts to provide geothermal heat to inhabitants of districts.
Oregon-HJR66	Directs that schools teach and practice skills of recycling and resource-energy conservation.
Virginia-H1809*	Virginia Solar Energy Center is created.

#### Management/Organization

Georgia-SR197*	Creates the Energy Production Study Committee.
Indiana-SCR41*	Creates a committee to study the transportation and energy crisis and the effects of federal fuel controls on transportation in Indiana.
Iowa-S314*	Relating to the regulation of surface coal mining, imposing additional fees and providing for violation of the act.
Kansas-S13*	Creates a Kansas Energy Office.

Maine-LD1558*	Creates the Maine Energy Development Fund.
Maine-S440(LD1456)*	Re-assigns the functions of the Department of Commerce and Industry and the Office of Energy Resources.
Nevada-A523*	Creates State Energy Resources Advisory Board.
Oregon-S483	Creates a Department of Energy.
Tennessee-H272(Vetoed)	Establishes the Tennessee Energy office and provides for its powers and duties.
Utah-H323*	Adds mining to division of oil and gas conservation and provides for rehabilitation of mined lands under the board.
Vermont-H407*	Establishes a department of energy planning.
West Virginia-H1293*	Continuing the commission on energy, economics and environment.
<hr/>	
Emergency Powers/Response	
Connecticut-H8303*	Concerning the grant of exemptions during an energy emergency.
Connecticut-H8555	Concerning an emergency energy assistant program.
Delaware-S86*	Extends the Governor's emergency powers to June 30, 1975
Idaho-S1138*	Relating to the curtailment of electrical or gas service during emergencies.
Maryland-S204*	Extends to a certain date certain powers of the Governor in emergency energy crisis situations.
Tennessee-S199*	Amends code which gives emergency powers to the government in the event of an energy emergency.
Vermont-S140*	Extends the emergency powers of the executive to deal with energy problems.
Wyoming-S41*	Repeals the 1974 Energy Emergency Powers Act, and fixes an expiration date of July 1, 1977.
<hr/>	
<u>Miscellaneous</u>	
Arizona-H2231*	Authorizes schools to transfer and reallocate monies from any operating funds to pay costs of heating and transportation fuels.
Connecticut-H5761*	Concerning suspension of delivery by fuel oil and bottled gas retailers.
Minnesota-S38*	Relating to education; requiring each school district to make reports concerning the consumption of energy.
Minnesota-S38*	Relating to education, requiring each school district to make reports concerning the consumption of energy.
Oklahoma-S145(Law)	Provides for creation, administration, merger and dissolution of rural natural gas distribution districts in same manner as provided.
Oregon-H3219*	Authorizes Department of Transportation to fix energy conservation speed limitation.
Rhode Island-H6050*	Relating to retroactive price adjustments for public work contracts involving the use of certain petroleum products.
<hr/>	

## REFERENCES

- [AEC-72] "Environmental Survey of Transportation of Radioactive Material To and From Nuclear Power Plants", Directorate of Regulatory Standards, U. S. AEC, Washington, D. C., December, 1972.
- [AEC-73-1] The Nuclear Industry 1973, U. S. AEC, WASH 1174-73.
- [AEC-73-2] "Operating History of U.S. Nuclear Power Reactors", WASH 203-73, 1973.
- [AEC-73-3] "The Safety of Nuclear Reactors and Related Facilities, AEC Report, WASH-1250, July, 1973.
- [AEC-74-1] "High Level Radioactive Waste Management Alternatives," United States Atomic Energy Commission, Report WASH-1297, May 1974.
- [AEC-74-2] "Survey of U.S. Uranium Marketing Activity," United States Atomic Energy Commission, Division of Production & Materials Management, Washington, D. C., April, 1974.
- [AEC-74-3] "Nuclear Power Growth, 1974-2000," United States Atomic Energy Commission, WASH-1139, February, 1974.
- [AEC-74-4] "Reactor Safety Study, An Assessment of Accident Risk in U. S. Commercial Nuclear Power Plants," Summary Report, Draft WASH-1400, August, 1974.
- [AF-73] The Architectural Forum, July, 1973.
- [AGA-72] A Hydrogen-Energy System, Prepared for this American Gas Association by the Institute of Gas Technology, written by D. P. Gregory, August, 1972.
- [AHC-75] "The Economics of Energy and Natural Resource Pricing," AD HOC Committee on the Domestic and International Monetary Effect of Energy and Other Natural Resource Pricing, U. S. Government Printing Office, 94th Congress, First Session, Committee Print, March, 1975.
- [AIA-74] AIA Research Corporation, Energy Conservation in Building Design, May, 1974.
- [Alexander-75] Alexander, Arthur D., United States Transportation Fuel Economics (1975-1995), NASA Technical Memorandum, TM X-3197, April, 1975.

R-1

- [Allen-75] Allen, Donald G., Vice President, New England Electric Systems  
Testimony before U. S. Senate Committee on Public Works on the  
Natural Petroleum and Natural Gas Conservation and Coal Substitution  
Act of 1975, June 12, 1975.
- [Ankrum-74] Ankrum, G. T., Lt., "The Nuclear-Electric Energy Economy,"  
Navy Engineer - Civil, Vol XV, No. 3, Fall, 1974.
- [APCSR-74] Alabama Power Company, Statistical Review, 1963-1973, 1974.
- [APS-75-1] "Efficient Use of Energy: A Physics Perspective," American  
Physical Society, A report of a summer study, Princeton, New Jersey,  
P. 95, July, 1975.
- [APS-75-2] Hartley, D. L., et al., "The Role of Physics in Combustion,"  
to be published as AIP Conference Proceedings, American Institute of  
Physics, 1975.
- [AU-72] Associated Universities, Inc., "Reference Energy Systems and  
Resource Data for Use in the Assessment of Energy Technologies," for  
Office of Science and Technology, April, 1972.
- [Austin-75] Austin, T. C., and Hellman, K. H., "Passenger Car Fuel Economy  
as Influenced by Trip Length," SAE, Automotive Engineering Congress'  
and Exposition, Paper #750004, February, 1975.
- [Bader-75] Bader, C., "Electrical Propulsion Systems for Battery Driven  
Road Vehicles with Hydrodynamic Transmission of Power," paper  
presented at Automotive Engineering Congress and Exposition, Detroit,  
Michigan, February 24-28, 1975.
- [Bartell-75-1] Bartell, Bill, Occidental Oil Shale Corporation, private  
communication, July 9, 1975.
- [Bartell-75-2] Bartell, Bill, Occidental Oil Shale Corporation, private  
communication, August, 1975.
- [BEA-73] Department of Commerce, Bureau of Economic Analysis, Business  
Statistics, 1973.
- [Beale-74] Beale, W. T., "A Stirling-Hydrostatic Drive for Small Vehicles,"  
Sunpower, Inc., Athens, Ohio, 1974.
- [Berry-73] Berry, S., & Fels, Margaret, "The Energy Cost of Automobiles,"  
Science & Public Affairs, December, 1973.
- [Berg-73] Berg, C. A., Conservation Via Effective Use of Energy at the  
Point of Consumption, April, 1973.
- [Blomeke-75] Blomeke, J. O., et. al., "Shipments in the Nuclear Fuel  
Cycle Projected to the Year 2000," Nuclear News, June, 1975.

R-2



- [BLS-75] "The Structure of the U.S. Economy in 1980 and 1985," Bulletin 1831, Bureau of Labor Statistics, 1975.
- [BNA-EUR-75] "Mini Computer Carburetor Regulator Control," Bureau of National Affairs, Energy Users Report, No. 85, p. D-1 & 2, March, 1975.
- [Bos-75] Bos, Dr. S. B., Manager Solar Program, Private Communication, Electric Power Research Institute, Palo Alto, California, August 11, 1975.
- [Brobst-74] Brobst, W., "Transportation of Nuclear Fuel and Waste," Nuclear Technology, Vol. 24, December, 1974.
- [Brown-71] Brown, L. T., "Energy and the Environment", Charles E. Merrill Publishing Company, Columbus, Ohio, 1971.
- [Brown-74] Brown, J. T. and Cromim, J. H., "Battery Systems for Peeking Power Generation, Intersociety Energy Conversion Engineering Conference, 1974.
- [Buchanan-74] Buchanan, J. R., "General Safety Considerations: Safeguards Against the Theft or Diversion of Nuclear Materials," Nuclear Safety, Vol. 15, No. 5, September-October, 1974.
- [Budwani-75] Budwani, R. N., "Nuclear Power Plants: What It Takes to Get Them Built," Power Engineering, June, 1975.
- [CA-75] Coal Age "Summary of Announced Plans for Coal Conversion Plants," p. 94, March, 1975.
- [CAC-74] Center for Advanced Computation, "Energy Cost of Goods and Services, 1963 and 1967," R. A. Herendeen and Clark W. Bullard, III, Document 140, 1974.
- [CAC-137P-74] Center for Advanced Computation, "Nuclear Power to 1985: Possible Versus Optimistic Estimates," M. Rieber and R. Halcrow, Document CAC-137P, November, 1974.
- [CAC-75] Center for Advanced Computation, "Direct Energy Use in the U. S. Economy, 1967," David Simpson and David Smith, Tech. Memo 39, 1975.
- [Carter-75] Carter, J. W., Fr., "The Carter System - A New Approach for a Steam Powered Automobile," SAE, Automotive Engineering Congress and Exposition, Paper #750071, February, 1975.
- [Chase-75] "Long Term Interindustry Forecasts," INFORUM, Chase Econometrics, 1975.
- [Coates-74] Coates, J. F. "Some Methods and Techniques for Comprehensive Impact Assessment", Technological Forecasting and Social Change, 6, 341-357, 1974.

R-3

- [Cohn-75] Cohn, Charles E., "Improved Fuel Economy for Automobiles," Technology Review, February, 1975.
- [Commoner-71] Commoner, Barry, The Closing Circle, Bantam Books, 1971:
- [Con-73] "Contributions to technology and their transfer, a NASA experience," presented at the NATO Advanced Study Institute on Technology Transfer, Paris-Evry, France, June 24 - July 6, 1973.
- [Copps-75] Copps, Stephen L., "Energy Survey: What Can R & D Do By 1985?", NASA, Washington D. C., 1975.
- [Creagan-74] Creagan, R. J., "The Nuclear Electric Economy As a Solution to the Energy Problem," Westinghouse Electric Corporation, June 28, 1974.
- [Day-74] Day, Lawrence H., "Factors Affecting Future Substitution of Communications for Travel," ORSA Paper at ORSA and IMS joint meeting, San Juan, Puerto Rico, October, 1974.
- [Dean-74] Dean, S. O., "Fusion Power: Types, Status, Outlook," Power Engineering, March, 1974.
- [Deutsch-74] Deutsch, R. M. and Whitney, J. N., "Nuclear Manpower Crises Ahead," Nuclear News, pp. 71-78, June, 1974.
- [Dickson & Bowers-73] Dickson and Bowers, The Video Telephone: A New Era in Telecommunications -- A Preliminary Technology Assessment, Cornell University, June, 1973.
- [Dietz-75] Dietz, R. J., and Bundada, M. V. A., "Urban Deployment of an Aerial Guideway People Mover in the Detroit CBD," SAE, Automotive Engineering Congress and Exposition, Paper #750446, 1975.
- [DOT-73-1] Department of Transportation, Low Cost Urban Transportation Alternatives: A Study of Ways to Increase the Effectiveness of Existing Transportation Facilities, Prepared by R. H. Pratt Associates, Inc., January, 1973.
- [DOT-73-2] Department of Transportation, "Summary and Analysis of Accidents on Railroads in the United States," Federal Railroad Administration, Accident Bulletin, No. 141 (5006-0011), Washington, D. C., 1973.
- [DOT-74] Department of Transportation, "1972 Accidents of Large Motor Carriers of Property," Federal Highway Administration, May, 1974.
- [DOT-75-1] Department of Transportation, Carpool and Buspool Matching Guide, Federal Highway Administration by Transit and Traffic Engineering Branch Urban Planning Division, January, 1975.
- [DOT-75-2] Department of Transportation, Carpool Incentives and Opportunities, A Report of the Secretary of Transportation to the United States Congress Pursuant to Section 3(e) P.L. 93-239, February, 1975.

R-4

- [DOT-75-3] Department of Transportation, Improving Urban Mobility; Through Better Transportation Management, Federal Housing Administration, Urban Planning Division, Transit and Traffic Engineering Branch, May, 1975.
- [DOT-EPA-75] Department of Transportation, Potential for Motor Vehicle Fuel Economy Improvement, Report to the Congress, Environmental Protection Agency, October, 1975.
- [DPD-75] Department of Planning and Development, "Montgomery Bikeway and Pilot Project," Montgomery, Alabama, April, 1975.
- [Dupree-72] Dupree, W. G. and West, J. A., United States Energy Through the Year 2000, U. S. Government Printing Office, Washington, D. C., 1972.
- [EC-75] Energy Conservation and Oil Policy Act of 1975, Report No. 94-340, House of Representatives, to accompany H. R. 7014, July 9, 1975.
- [EEA-74] Energy and Environmental Analysis, Inc., "Energy Management in Manufacturing: 1967 - 1990," Draft Report prepared for Council on Environmental Quality, August, 1974.
- [El-Badry-74] El-Badry and Zemkoski, J., "The Potential for Rechargeable Storage Batteries in Electric Power Systems," S & L Intersociety Energy Conversion Engineering Conference, California, August 26-30, 1974.
- [ENERGY-75] Stoker, Seager, and Capener, Energy - From Source to Use, Scott, Foresman and Company, 1975.
- [EPIC-75] "Energy Conservation Program Guide for Industry and Commerce," NBS Handbook 115, U. S. Department of Commerce, September, 1974.
- [EPRI-75] Electric Power Research Institute, "A Summary of Program Emphasis for 1975," Palo Alto, California, 1975.
- [ERC-71] "Electric Utilities Industry Research and Development Goals Through the Year 2000," Report of the R & D Goals Task Force to the Electric Research Council, June, 1971.
- [ERC-72] "Underground Power Transmission," A study for the Electric Research Council, ERC publication 1-72, Arthur D. Little, Inc., Cambridge, Massachusetts, October, 1971.
- [EROA-75] A National Plan for Energy Research, Development and Demonstration, Volume 1, Supt. of Documents, 28, June, 1975.
- [EULMC-74] Electric Utility Load Management Conference, NATO Committee on Challenges on Modern Society, Office of Industrial Analysis, FEA, Brussels, November 12-13, 1974.
- [EW-74] Electric World, p. 131, June 1, 1974.

- [EW-75] "Generation Additions Exceed 1974 Need," Electrical World, p. 58, March 15, 1975.
- [Ezra-75] Ezra, A. A. Science, 187, 707, 1975.
- [Faber-75] Faber, John, The National Ash Association, Private Communication, July 18, 1975.
- [FAI-74] Foster Associates, Inc., Energy Prices, 1960-73, Ballinger, Cambridge, Massachusetts, 1974.
- [FEA-74] Federal Energy Administration, "The Data Base - The Potential for Energy Conservation in Nine Selected Industries," June, 1974.
- [Fellmeth-70] Fellmeth, Robert, The Interstate Commerce Omission, Grossman Publishers, New York, 1970.
- [FEM-71] Moss, F. E., "Energy Related Research and Development," Senate Committee on Aeronautical and Space Sciences, Committee Print, 1974.
- [Fisher-74-1] Fisher, F. G., "Tomorrow's Railroads," Mechanical Engineering, April, 1974.
- [Fisher-74-2] Fisher, John C., "Energy Crisis in Perspective," John Wiley and Sons, New York, 1974.
- [Flannery-75] Flannery, Dr., Land of Water Resources, Office of Assistant Secretary, Department of Interior, Personal Communications, August 8, 1975.
- [Fleming-75] Fleming, R. D., and Chamberlain, T. W., "Methanol as Automotive Fuel, Part 1 - Straight Methanol," SAE, Automotive Engineering Congress and Exposition, Paper # 750121, February, 1975.
- [Flynn-73] Flynn, T. M., R. L. Powell, D. R. Chelton, and B. W. Birmingham, "Superconducting Electrical Generators for Central Power Station Use," Proceedings of 1973 Cryogenic Engineering Conference, Georgia Tech., Atlanta, Georgia, p. 35-43, August 8-10, 1973.
- [Forbes-74] Forbes, I. A., et. al., "The Nuclear Debate: A Call to Reason," A Position Paper, Atomic Industrial Forum, Inc., Public Affairs and Information Program, June 19, 1974.
- [Ford-74] "A Time to Choose," The Energy Policy Project of the Ford Foundation, Ballinger Publishing Company, Cambridge, Massachusetts, 1974.
- [FPC-73] Energy Distribution Research, Technical Advisory Committee on R & D, The National Power Survey, Federal Power Commission, December, 1973.
- [FPC-74] Research and Development for the Electric Utility Industry, Technical Advisory Committee on R & D, The National Power Survey, Federal Power Commission, July, 1974.

R-6

- [FPC-F0-74] Federal Power Commission, National Power Survey, The Financial Outlook For the Electric Power Industry, December, 1974.
- [GA-74] "The Data Base - The Potential for Energy Conservation in Nine Selected Industries," Gordion Associates, Inc., New York, New York, June, 1974.
- [Gallager-75] Gallager, John, Vice President, American Lurgi, Personal communication, July 29, 1975.
- [GE-74-1] "Solar Heat Pumps Conserve Scarce Fuels," General Electric Company, Schenectady, New York, 1974.
- [GE-74-2] "Energy: Beyond the Crisis", V. A. Rydbeck, General Electric Company, Address delivered at National Electrical Week Luncheon, Electrical Association of Rochester, Inc., Rochester, New York, February 11, 1974.
- [GE-75-1] State of California Energy Resources Conservation and Development Commission (Docket No. 75-FOR-5), Comments on the statement of the Environmental Defense Fund by the General Electric Company, Major Appliance Business Group, D. W. Lynch, Vice President and General Manager, Engineering Division, Major Appliance Business Group, General Electric Company, 1975.
- [GE-75-2] "Heat Pump Training Ahead of Schedule" & "Heat Pump - Made to Order," Load Currents, no. 32, V. A. Rydbeck, Manager, General Electric Company, Fairfield, Connecticut, August, 1974.
- [Gilpin-75] Gilpin, Robert, "Technology, Economic Growth, and International Competitiveness," A Report for the Subcommittee on Economic Growth of the Joint Economic Committee--Congress of the United States, July 9, 1975.
- [Glemming-75] Glemming, D. A. & Bowers, P. A., "Tire Testing for Rolling Resistance and Fuel Economy," SAE, Automotive Engineering Congress, Paper #750457, February, 1975.
- [Gray-73] Gray, Dr. Allan G., Technical Director, American Society for Metals, Private communication, July 17, 1973
- [Gregory-73] Gregory, Derek P. and Rosenberg, Robert B., "Synthetic Fuels for Transportation and National Energy Needs," Energy and the Automobile, SP-383, Society of Automotive Engineers, Inc., July, 1973.
- [GSA-74] "Energy Conservation Guidelines for New Office Buildings," General Services Administration, 1974.
- [GT-75] Grant, P. Thompson, Environmental Law Institute, Presentation made to NASA-ASEE Design Group, Huntsville, Alabama, June, 1975.
- [Hafer-75] Hafer, Paul R., Dicker, Arthur, Jr., & Yoder, Harry D., "The Electric Multistop Fleet Delivery Vehicle - Fact or Fantasy," paper presented at the Automotive Engineering Congress and Exposition held at Detroit, Michigan, February 24-28, 1975.

R. Y

- [Hannon-75] Hannon, B., "Energy Conservation and the Consumer," Science, 189, p. 95, 1975.
- [Harkness-72] Harkness, Richard, "Communications Substitutes for Intra-Urban Travel," Transportation Engineering Journal: Proceedings of the American Society of Civil Engineers, August, 1972.
- [Hearings-75] "The Economics of Energy and Natural Resource Pricing," A compilation of reports and hearings of the Ad Hoc Committee of the Domestic and International Monetary Effect of Energy and Other Natural Resource Pricing, March, 1975.
- [Heck-75] Heck, Richard A., "Mass Transportation Vehicles and People Movers," Paper presented at the Automotive Engineering Congress and Exposition held at Detroit, Michigan, February 24-28, 1975.
- [Heyburn-75] Heyburn, Don, Vice President, Babcock and Wilcox, Personal communication, T-79, July 16, 1975.
- [Heydinger-74] Heydinger, E. R. (Chairman), Potential for Energy Conservation in the United States: 1974-1978 Transportation, National Petroleum Council, September, 1974.
- [Hill-70] Hill, P. H., The Science of Engineering Design, Holt, Rinehart and Winston, 1970.
- [Hirst-73] Hirst, Eric, "Energy Intensiveness of Passenger and Freight Transport Modes: 1950-1970," Oak Ridge National Laboratory, Oak Ridge, Tennessee, 1973.
- [Hodgson-74] Hodgson, S. W., "Alternate Fuels for Transportation - Part 3: Ammonia for the Automobile," Mechanical Engineering, July, 1974.
- [Hogerton-75] Hogerton, J. F., "U. S. Uranium Supply and Demand, Near Term and Long Range, Nuclear News, May, 1975.
- [Holder-75] Holder, R., "Fuel Conservation Measures: The Transportation Sector - Volume II", Texas Transportation Institute, Texas A & M University, January, 1975.
- [Holdren-73] Holdren, J. P., "Population and the American Predicament," Daedalus, Journal of the American Academy of Arts and Sciences, Vol. 102, No. 4, 1973.
- [Holt-75] Holt, W. J. & Samusson, L., "PRT Impact on Transportation," SAE, Automotive Engineering Congress and Exposition, Paper #750445, February, 1975.
- [Hottel-71] Hottel, H. C. & Howard, J. B., New Energy Technology--Some Facts and Assessments, The MIT Press, 1971.

R-B

- [Hough-75] Hough, Roger & Dickson, E., Personal phone conversation, Stanford Research Institute, Menlo Park, California, July, 1975.
- [Houthakker-74] Houthakker, Henrik & Kennedy, Michael, "Demand for Energy as a Function of Price," unpublished manuscript, 1974.
- [HR 7014 Hearings-75] Hearings before the Subcommittee on Energy and Power, Committee on Interstate Commerce, House of Representatives, 94 Congress, 1st session, Serial No. 94-18, 1975.
- [Hurter-75] Hurter, D. A. & Lee, W. D., "A Study of Technological Improvements in Automobile Fuel Consumption," SAE, Automotive Engineering Congress and Exposition, Paper #750005, February, 1975.
- [HY-73] "A Hydrogen Energy Carrier, Volume II Systems Analysis," NASA/ASEE, Systems Design Institute, NASA Grant NGT 44-005-114, 1973.
- [IEC-75] Industrial Energy Conservation Program Fact Sheet, Office of Industrial Programs, Conservation and Environment, FEA, June, 1975.
- [Ingamells-75] Ingamells, J. C. & Lindquist, R. H., "Methanol as a Motor Fuel or a Gasoline Blending Component," Paper presented at the Automotive Engineering Congress and Exposition, Detroit, Michigan, February 24-28, 1975.
- [ITC-71] Inter Technology Corporation, "The U. S. Energy Problem," Volume II, Appendices, Part B, November, 1971.
- [JCAE-75] Joint Committee on Atomic Energy Hearing, Volume 21, No. 19, May 12, 1975.
- [Johnson-75-1] Johnson, Bill, NASA, Lewis, Private Communication, July 9, 1975.
- [Johnson-75-2] Johnson, M., Professor Food Technology, Clemson University, South Carolina, Private telephone communication (cf. Telecon: No. 125), August 6, 1975.
- [Jones-74] Jones, L. W., "Liquid Hydrogen as a Fuel for Motor Vehicles: A Comparison with other Systems," Intersociety Energy Conversion Engineering Conference, 1974.
- [JPL-75] Jet Propulsion Lab, Status Report Geothermal Definition Project (Parts I & II), April 4, 1975.
- [Kalhammer-74] Kalhammer, F. R. & Zygiefbaum, P. S., "Potential for Large Scale Energy Storage in Electric Utility Systems," ASME, 74-WA/Ener.9
- [KOT-73] Kottenstette, J. P. & Rusnick, J. J., Resident Manager, 16 24, July, 1973.

A-9

- [Krzyczkowski-74] Krzyczkowski, Roman & Henneman, Suzanne S., Reducing the Need for Travel, UMTA Report No. UMTA CA-06-0045-2, March, 1974.
- [Krzyczkowski-75] Krzyczkowski, Henneman, Hidson, Putman, and Thiesen, Joint Strategies for Urban Transportation, Air Quality and Energy Conservation, Volume 1, Joint Action Programs Interplan Report 7326R, Urban Mass Transportation Administration, Washington, D. C., January, 1975.
- [Kubo-73] Kubo, A. S. & Rose, D. J., "Disposal of Nuclear Wastes, Science, p. 1209, December, 1973.
- [Kucera-75] Kucera, G., Plust, J. G., & Schneider, C., "Nickel-Zinc Storage Batteries as Energy Sources for Electric Vehicles," Paper presented at the Automotive Engineering Congress and Exposition, Detroit, Michigan, SAE, February 24-28, 1975.
- [Kummer-75] Kummer, J. T., "The Automobile as an Energy Converter," Technology Review, February, 1975.
- [Lancaster-75] Lancaster, T. A. & Hearn, D. L., "Mass Transportation: A National Commitment," Paper presented at the Automotive Engineering Congress and Exposition held at Detroit, Michigan, Society of Automotive Engineers, Inc., February 24-28, 1975.
- [Lathey-75] Lathey, Charles E., Telecommunications Substitutability for Travel: An Energy Conservation Potential," U. S. Department of Commerce, Office of Telecommunications Publication, January, 1975.
- [Lawson-74] Lawson, L. J., "Kinetic Energy Storage for Mass Transportation," Mechanical Engineering, pp. 36-42, September, 1974.
- [LC-75] Conta, Lewis, Testimony before the House Subcommittee on Energy and Power, published in Volume II of Hearings on the Energy Conservation and Oil Policy Act (serial no. 94-18), March 19, 1975.
- [LEA-69] Leatherman, A. F. & Stutz, D. E., "Induction Heating Advances: Application to 5800°F," 1969.
- [Little-74] A. D. Little, Inc., "Residential and Commercial Energy Consumption & Conservation," Project Independence Task Force Report, 1974.
- [Littmann-75] Littmann, D. L., "Business Briefs," Manufacturers National Bank of Detroit, June, 1975.
- [Lockheed-75] Lockheed Missiles & Space Company, Inc., "Ocean Thermal Energy Conversion - A New Power Source for the Nation," 1975.
- [Love-74] Love, Sam, "Short-Loop Living," Equilibrium, Vol. 2, No. 3, pp. 43-46, July, 1974.
- [LS-75] Stewart, L., ERDA, Presentation made to NASA-ASEE Design Group, Huntsville, Alabama, June, 1975.

R-10



- [Luchter-75] Luchter, S. & Mirsky, W., "A Survey of Automotive Rankine Cycle Combustion Technology," SAE, Automotive Engineering Congress and Exposition, Paper #750067, February, 1975.
- [MCF-75] McFadden, J. & Ass, E., Presentation made to NASA-ASEE Design Group, Huntsville, Alabama, July, 1975.
- [McFall-75] McFall, John H., Director, Public Relations and Advertising, El Paso Natural Gas Company, Personal communication, July 25, 1975.
- [Malliaris-73] Malliaris, A. C., Strombotne, R. L., "Demand for Energy by the Transportation Sector and Opportunities for Energy Conservation", ASME; Paper number 73-ICT-87; September, 1973.
- [Mascy-74] Mascy, A. C., Paullin, R. L., "Transportation Vehicle Energy Intensities", A Joint DOT/NASA Reference Paper, DOT-TST-13-74-1, NASA TM X-62,404, June, 1974.
- [Masey-75] Mascy, Alfred C., and Williams, Louis J., "Air Transportation Energy Consumption: Yesterday, Today, and Tomorrow", AIAA Paper 75-319, AIAA 11th Annual Meeting, Washington, D.C., February 24-26, 1975.
- [MEGASTAR-74] "Meaning of energy growth: an assessment of systems, technologies, and Requirements", September, 1974.
- [Meyerhoff-73] Meyerhoff, R. W., "Development of a Ragid A Superconducting Power Transmission Line", Proceedings of the 1973 Cryogenic Engineering Conference, Georgia Institute of Technology; Atlanta, Georgia; pages 101-108, August 8-10, 1973.
- [Mitre-72] Mitre Corporation, "Economy and Efficiency in the Energy System," for Environmental Protection Agency, July, 1972.
- [Moe-68] Moeller, E. C., et. al, "NASA Contributions to Development of Special Purpose Thermocouples, NASA Publication SP-5050, 1968.
- [Monti-75] Monti, Dario, Administrator, "Cool Gassification Technology Development", ERDA, Private communication, July 25, 1975.
- [Morris-75] Morris, C., "Silent Rider - A Project for City Center Transport", Paper presented at the Automotive Engineering Congress and Exposition, Detroit, Michigan, February 24-28, 1975.
- [Murphy-75] Murphy, Zane, Personnel Communications, August 7, 1975.
- [Mutch-71] Mutch, James J., "Transportation Energy Use in the United States: A Statistical History, 1955-1971," Report R-1391-NSF, Rand Corporation, Santa Monica, California, 1971.
- [Mutch-73] Mitch, James J., "The Potential for Energy Conservation in Commercial Air Transport," Report 12-1360-NSF, Rand Corporation, October, 1973.

R-11

- [MVMA-74] MVMA, "Cars Found More Efficient Than Mass Transit," Automotive Information, Motor Vehicle Manufacturers' Association, Vol. III, N. 1, August/September, 1974.
- [NAS-74] "Materials Technology in the Near-Term Future", National Academy of Science, 1974.
- [NASA-69] "Advancements in Teleoperator Systems", NASA-SP-5081, NASA, February, 1969.
- [NEI-75] Nuclear Engineering International, Supplement, April, 1975.
- [NI-75-1] Nuclear Industry, p. 3, June, 1975.
- [NI-75-2] "Price-Anderson Amendment," Nuclear Industry, p. 10, June, 1975.
- [NI-75-3] "Two-Firm Venture for Centrifuge Enrichment Plant Proposed," Nuclear Industry, p. 14, June, 1975.
- [NI-75-4] "U. S. Nuclear Plant Operating Experience", Nuclear Industry, p. 24, June, 1975.
- [NI-75-5] "Mining/Milling, Enrichment, Reprocessing Lead Requirements," Nuclear Industry, p. 37, June, 1975.
- [NI-75-6] "Mining/Milling, Enrichment, Reprocessing Lead Requirements", Nuclear Industry, p. 38, June, 1975.
- [Nielsen-75] Nielsen, George F., Editor in Chief, "Coal Mine Development Survey Shows 236.6 Million Tons of New Capacity", Coal Age, Keystone Coal Industry Manual, p. 130, 1975.
- [NN-75-1] Nuclear News, p. 36, July, 1975.
- [NN-75-2] "Major Nuclear Legislation of 94th U.S. Congress", Nuclear News, p. 55, July, 1975.
- [Nondahl-75] Nondahl, T. A., & Novotny, D. W., "A Method for Estimating Mileage Improvement and Emission Reductions Achievable by Hybrid-Electric Vehicles", Society of Automotive Engineers, Paper #750194, Automotive Engineering Congress and Exposition, Detroit, Michigan, February, 1975.
- [NPC-74-1] NPC, "Potential for Energy Conservation in the United States: 1974-1978", A report of the National Petroleum Council, Washington, D. C., September 10, 1974.
- [NPC-74-2] NPC, "Potential for Energy Conservation in the United States, 1974-1978, Residential/Commercial", A report of the National Petroleum Council, Washington, D. C., 1974.
- [NPC-74-3] NPC, "Potential for Energy Conservation in the United States: 1974-1978, Transportation", A report of the National Petroleum Council, Washington, D. C., September 10, 1974.

R-12

- [Obert-63] Obert, E. F. & Gaggioli, Richard, Thermodynamics, McGraw-Hill Book Company, New York, 1963.
- [O'Connell-73] O'Connell, W. H., "Ride Free, Drive Free", The John Day Company, 1973.
- [OGJ-73] Oil and Gas Journal, Ted Wett, Petrochemical Editor, p. 131, June 25, 1973.
- [Overby-74-1] Overby, C. M.; Hutchison, J. & Wiercinski, R., "Transportation-Communications Trade Offs: Some Employment Implications for Home Bound Persons--Vocational Prostheses", Paper for the Seventh International Symposium on Human Factors in Telecommunications, pmtrreal, September 22-27, 1974.
- [Overby-74-2] Overby, C. M., "New Patterns of Work Organization in an Information Era: Transportation-Communications Trade Offs", Paper at ASEE Annual Conference, R. P. I., Troy, New York, June 18, 1974.
- [Papamarcos-74] Papamarcos, "King Coal's Last Chance", Power Engineering, p. 39, March 1974.
- [Pastuhov-74] Pastuhov, "Status Report on LNG Tanker Designs; Advances in Cryogenic Engineering", Vol. 19, Plenum Press, New York and London, 1974.
- [PCA-74] Portland Cement Association, "The U. S. Cement Industry, An Economic Report", March, 1974.
- [Penner-74] Penner, Peter, S., "The Energy and Labor Intensity of Walking", CAC Technical Memorandum, No. 29, University of Illinois, October, 1974.
- [Penner-75] Penner, S. S. & Icerman, L., "Energy, Non-nuclear Technologies", Vol. II, Addison-Wesley Publishing Company, Inc., 1975.
- [PFE-74] Gyftopoulos, Elias P., Lazaridis, Lozaros J., & Widmer, Thomas F., "Potential Fuel Effectiveness in Industry", Ballinger Publishing Company, Cambridge, Massachusetts, 1974.
- [Pierce-75] Pierce, J. R., "The Fuel Consumption of Automobiles", Scientific American, January, 1975.
- [Powell-75] Powell, T., "Racing Experiences with Methanol and Ethanol-Based Motor-Fuel Blends", Automotive Engineering Congress and Exposition, Detroit, Michigan, February 24-28, 1975.
- [PI-1] Project Independence Executive Summary, Superintendent of Documents.
- [PI-74-1] Project Independence Report, A report of the Federal Energy Administration, November, 1974.

R-13

- [PI-74-2] Project Independence, "Oil: Possible Levels of Future Production," Project Independence Blueprint Final Task Force Report, Superintendent of Documents, 4118-00017, 1974.
- [PI-74-3] Project Independence, "Synthetic Fuels From Coal", Project Independence Final Task Force Report, Superintendent of Documents, 4118-00010, 1974.
- [PI-74-4] Project Independence, "Natural Gas", Project Independence Final Task Force Report, Superintendent of Documents, 4118-00014, 1974.
- [PI-74-5] Project Independence, "Residential and Commercial Energy Use Patterns", Project Independence Blueprint Final Task Group Report, Superintendent of Documents, U. S. Government Printing Office, 4118-00038, 1974.
- [PI-74-6] Project Independence, "Inputs to the Project Independence Evaluation System Integration Model for Transport of Energy Materials", Vol. II, Final Task Force Report, 4418-00030, 1974.
- [PI-74-7] Project Independence, "The Data Base: The Potential for Energy Conservation in Nine Selected Industries", Vol. 2, Petroleum Refining, 1975.
- [PI-74-8] Project Independence, "Transcript of Public Hearings", Chicago, Appendix, Superintendent of Documents, U. S. Government Printing Office, 041-018-00043, 1974.
- [PI-74-9] Project Independence, "Potential Future Role of Oil Shale: Prospects and Constraints", Final Task Force Report, 1974.
- [PI-74-10] Project Independence, Draft Report of the Solar Energy Task Force for Project Independence Blueprint.
- [PI-74-11] Project Independence, "Project Independence and Energy Conservation: Transportation Sectors", Final Task Group Report, Vol. 2, p. 11-74, 4118-00039, Superintendent of Documents, U. S. Government Printing Office, Washington, D. C., 1974.
- [PI-74-12] Project Independence, "Energy Conservation in the Manufacturing Sector, 1954-1990", Final Task Group Report, Vol. 3, p. 11-74, 4118-00040, Superintendent of Documents, U. S. Government Printing Office, Washington, D. C., 1974.
- [PI-74-14] Project Independence, "Task Force Report on Labor", 1974.
- [PI-74-15] Project Independence, Water Resources Study, 1974.
- [Pilati-74] Pilati, D., Airplane Energy Use and Conservation Strategies, Report ORNL-NSF-EP-69, Oakridge National Labs, May, 1974.
- [PMV-74] "Potential for Motor Vehicle Fuel Economy Improvement", Report to the Congress by DOT and EPA, October, 1974.

R-124

- [Podolny-75] Podolny, Bill, United Technology Corporation, Personal communication, July 8, 1975.
- [Pollaert-75] Pollaert, Sales Manager, American Lurgi, Personal communication (T-109), July 31, 1975.
- [Pollard-75] Pollard, Hiatt & Kiplow, "Summary of Opportunities to Conserve Transportation Energy", Transportation Systems Center, A report for the Office of the Secretary, January, 1975.
- [Poole-75] Poole, L. G., "World Uranium Resources", Nuclear Engineering International, p. 97, February, 1975.
- [Power-74] Power, "Fossil-Fired Central Stations", S.8, November, 1974.
- [PRE-74] Prengle, H. W., Jr., "Potential for Energy Conservation in Industrial Operations in Texas," University of Houston, November, 1974.
- [PRE-75] Prengle, H. W., Jr., University of Houston, Presentation made to NASA-ASEE Design Group, Huntsville, Alabama, June, 1975.
- [PU-73] "Energy Consumption for Residential Space Heating", Report #4, Princeton University, [P.U. #4-73], September, 1973.
- [Reed-74] Reed, Raymond D., "The Impact of and Potential for Energy Conservation Practices in Residential and Commercial Buildings in Texas", Texas A & M University, December 10, 1974.
- [Reistad-74] Reistad, G. M., "Available Energy Conversion and Utilization in the United States", Trans. of ASME 74-WA/Pwr-1, 1974.
- [Renner-75] Renner, R. A. & Wenstrom, M., "Experience with Steam Cars in California", SAE, Automotive Engineering Congress and Exposition, Paper #750069, February, 1975.
- [Rice-74] Rice, R. A., "Toward More Transportation with Less Energy", Technology Review, pp. 45-53, February, 1974.
- [Ridley-75] Ridley, Dick, Occidental Oil Chale Corporation, Private communication, July 10, 1975.
- [RMP-75] "Report to the American Physical Society by the Study Group on Light-Water Reactor Safety", Reviews of Modern Physics, Vol. 47, Supplement No. 1, p. 51-5124, Summer, 1975.
- [ROB-72] Robbius, M. D., et. al., "Mission Oriented R & D and the Advancement of Technology: The Impact of NASA Contributions", Vol. I, 1972.
- [Rotty-74-1] Rotty, R. M., "Waste Heat Disposal From Nuclear Power Plants", National Oceanic and Atmospheric Administration, Technical Memo ERL-ARL-47, September, 1974.

R-15

- [Rotty-74-2] Rotty, R. M., "Atmospheric Thermal Pollution", Presented at Climatology Conference and Workshop of the American Meteorological Society, Ashville, North Carolina, October, 1974.
- [Ruedisili-75] Ruedisili, Lon C. & Firebaugh, Morris, "Perspectives on Energy", Oxford University Press, New York, 1975.
- [Rybeck-75] Rybeck, Vernon A. & Sigley, Richard M., "Planning to Improve Utility Profitability", American Power Conference, Chicago, April, 1975.
- [Ryder-73] Ryder, N. B., "Two Cheers for ZPG", Academy of Arts and Sciences, Daedalus, Journal of the American, Vol. 102, No. 4, 1973.
- [SAE-75] Author unknown, "Use of Aluminum in Automobiles - Effect on the Energy Dilemma", SAE, Automotive Engineering Congress and Exposition, Paper No. 750421, February, 1975.
- [Santemaro-75] Santemaro, Anthony, Professor of Finance, Wharton School of Finance, University of Pennsylvania, Private communication, July 18, 1975.
- [SCB-74] Survey of Current Business, February, 1974.
- [Schaefer-75] Schaefer, James C., "Characteristics of the Carb Tek<sup>R</sup> Molten Salt Battery", Paper presented at the Automotive Engineering Congress and Exposition, Detroit, Michigan, February 24-28, 1975.
- [Schneider-75] Schneider, P. H., "Steam Power Systems California Clean Car Project", SAE, Automotive Engineering Congress and Exposition, Paper #750070, February, 1975.
- [Schumacher-73] Schumacher, E. F., Small is Beautiful: Economics as if People Mattered, Harper Torchbook, 1973.
- [SCI-74] Steinhart, T. S. & Steinhart, C. E., "Energy Use in the United States - Ford System", Science, Vol. 184, pp. 307-316, 1974.
- [SCI-75-1] Hannon, Bruce, "Energy Conservation and the Consumer", Science, Vol. 189, July, 1975.
- [SCI-75-2] Lindsley, E. F., "Total Energy System", Popular Science, August, 1975.
- [SCI AM-71] Cook, Earl, "The Flow of Energy in an Industrial Society", Scientific American, p. 136, September, 1971.
- [SESA-73] Subcommittee on Energy of the Committee on Science and Astronautics, "Energy Facts", House of Representatives, 93rd Congress, First Session, November, 1973.
- [Schuldiner-75] Schuldiner, Herbert, "Battery-Powered Cars You Can Buy Now", Popular Science, June, 1975.

R-16

- [Silien-75] Silien, Joseph S., "Highlights of UMTA's Rail Program", Paper presented at the Automotive Engineering Congress and Exposition held at Detroit, Michigan, SAE, February 24-28, 1975.
- [Simon-75] Simon, "Capital Investment: An Urgent Need", Treasury Papers, pp. 4-7, July, 1975.
- [Skidmore-75] Skidmore, Owings & Merrill System Design Concepts, Inc., "Energy, The Economy, and Mass Transit", for the United States Congress, Office of Technology Assessment, Prepared under Contract OTA C-4, June, 1975.
- [Slick-75] Slick, W. T., Jr., Statement before the Senate Committee on Finance, July, 1975.
- [Small-74] Small, W. J., Fetterman, D. E., & Bonner, T. F., Jr., "Alternate Fuels for Transportation - Part 1: Hydrogen for Aircraft", Mechanical Engineering, May, 1974.
- [Smart-75] Smart, Dale, President, Dale Smart Truck Lines, Inc., Private communication, July 15, 1975.
- [Spencer-75] Spencer, D., Solar Energy: A View From an Electric Utility Standpoint, Electric Power Research Institute, April, 1975.
- [SRI-72] "Patterns of Energy Consumption in the U. S.", by Stanford Research Institute, Menlo Park, California, U. S. Government Printing Office, January, 1972.
- [SRI-74] Stanford Research Institute, Refuse as a Fuel for Utilities, 1974.
- [Stewart-74] Stewart, W. F. & Edeskuty, F. J., "Alternate Fuels for Transportation - Part 2: Hydrogen for the Automobile", Mechanical Engineering, June, 1974.
- [Stocky-75] Stocky, J. F., Dowdy, M. W. & Vanderbrug, T. G., "An Examination of the Performance of Spark Ignition Engines Using Hydrogen - Supplemented Fuels", SAE, Automotive Engineering Congress and Exposition, Paper #750027, February, 1975.
- [Stoker-75] Stoker, Seager, Carpenter, From Source To Use Energy, 1975.
- [Stuntz-75] Stuntz, M. S., Jr., "Mass Transit and Energy Conservation", FEA, March 5, 1975.
- [Swallow-75] Swallow, S. E., "A Review of Successful Fuel Conservation Measures for Motor Vehicle Fleets", SAE, Automotive Engineering Congress and Exposition, Paper #750072, February, 1975.
- [TAMPAT-75] Bernstein, Peter, J., "Oil Refineries...Pollution Standards Called Reasonable", Tampa Times, July 26, 1975.

R-17

- [TERRASTAR-73] "Terrestrial Application of Solar Technology and Research", TERRASTAR, NASA CR-129012, University Affairs Office Headquarters, NASA, September, 1973.
- [Tillman-75] Tillman, Spilman, O. L. R., Beach, J. M., "Potential for Methanol as an Automotive Fuel", SAE, Automotive Engineering Congress and Exposition, Paper #750118, February, 1975.
- [TJ-74] Jayadevaiah, T. S. & Chin, S. C., "Economics of a Hydrogen Storage Peeking Power Plant", ASME, 74-WA/Pwr-6, 1974.
- [Tully-75] Tully, Jack, Vice President, Combustion Engineering, T-77, Personal Communication, August 15, 1975.
- [Tyler-74] Tyler, M., Cartwright, B., & Bush, G., "Interaction Between Telecommunications and Face-to-Face Contact: The Energy Factor", Long-Range Intelligence Bulletin 3, British Post Office, September, 1974.
- [UMTA-74] Paratransit: A Summary Assessment of Experience and Potential, U. S. Department of Transportation, Urban Mass Transportation Administration, Federal Highway Administration, June, 1974.
- [Van Vleck-74] Van Vleck, E. M., "Substituting Telecommunications for Travel: Feasible or Desirable?", Paper presented at the IEEE National Telecommunications Conference, San Diego, California, December 3-5, 1974.
- [Van Zee-74] Van Zee, John W., "Methane From Landfill; Survey of Existing Bay Area Sites", 1974.
- [Vanderslice-74] Vanderslice, Thomas A., "Today's Obvious Incentive to Electrify Railroads", Load Currents, No. 33, General Electric Company, Fairfield, Connecticut, November, 1974.
- [Voorhees-74] Voorhees and Associates Inc., Guidelines to Reprice Energy Consumption Through Transportation Actions, Urban Mass Transportation Administration, May, 1974.
- [Walters-75] Walters, Samuel, "High Performance Battery", Mechanical Engineering, July, 1975.
- [WE-64] Electrical Transmission and Distribution Reference Book, Westinghouse Electric Corporation, Pennsylvania, 1964.
- [WEC-74] World Energy Conference Survey of Energy Resources; The United States National Committee of the World Energy Conference, McGregor and Werner, Inc., Washington, D. C., 1974.
- [Weedy-72] Weedy, B. M. Electric Power Systems, John Wiley and Sons (Second Edition), 1972.

R-18



- [Weiner-75] Weiner, Steven A., "An Overview of the Sodium-Sulfur Battery", Paper presented at the Automotive Engineering Congress and Exposition, Detroit, Michigan, SAE, February 24-28, 1975.
- [Weiss-75] Weiss, Al, Manager, Coal Gasification Program, Natural Gas Pipeline Company of America, Personal communication, T-104, July 28, 1975.
- [Wells-75] Wells, Exxon Inc., Personal communication, July, 1975.
- [WEST-75] "Electrical Loads Offering Major Potentials for Use of Off-Peak Power", Westinghouse: The Energy Utilization Project, Power System Planning Department, Pittsburgh, Pennsylvania, Contact D. J. Walakas, 1975.
- [Whalen-75] Whalen, T. J., "Conductive Ceramics for Use in the Na-S Battery", Paper presented at the Automotive Engineering Congress and Exposition, Detroit, Michigan, February 24-28, 1975.
- [Winsche-73] Winsche, W. E., Hoffman, K. C., & Salzamo, F. J., "Economics of Hydrogen Fuel for Transportation and Other Residential Applications," Intersociety Energy Conversion Engineering Conference, 1973.
- [Wortham-75] Wortham, Bill, Private communication, FEA, 1975.
- [Wyman-69] Wyman, Bryce W., "Electrification: The Key to More Efficient Transportation", An address at the Marketing Conference for Electric Utility Executives, Louisville, Kentucky, General Electric Company, February, 1969.
- [WYOMING-74] Wyoming Coal Gas Company & Rochelle Coal Company, "Proposed Coal Gasification Project", Campbell and Converse Counties, Wyoming, SERNCO, October, 1974.
- [Young-75] Young, Jack, Edison Electric Institute, Personal communication, T-27, June 23, 1975.

A-19

Previous summer studies by the Auburn/Marshall Summer Faculty Fellowships Systems Engineering Design Groups have produced the following reports and are available as indicated from the Engineering Extension Service, Auburn University, Auburn, Alabama 36830:

PROGRAM YEAR	TITLE OF STUDY AND REPORT	
1969	STARLAB	- An Orbiting Space Technology Applications & Research Laboratory *
1970	UNISTAR	-User Network for Information Storage, Transfer, Acquisition, and Retrieval *
1971	STARSITE	-Search to Assess Resources, Social, Institutional, Technical, and Environmental *
1972	ERISTAR	-Earth Resources Information Storage, Transformation, Analysis, and Retrieval *
1973	TERRASTAR	-TERRestrial Application of Solar Technology And Research **
1974	MEGASTAR	-The Meaning of Energy Growth: An Assessment of Systems, Technologies and Requirements ***

\* \$1.00 handling charge per copy

\*\* Available from National Technical Information Service, Washington, D. C.

\*\*\* \$5.00 per copy

B-20